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The purpose of this project was to demonstrate minimizing system-wide inventories of end-of tariff long sleeved men's dress shirts for Parris Island by using VPV and CARGOES to manufacture a level quantity of 100 shirts per week. Manufacturing emphasis was on maximizing automation to minimize costs.

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Clemson Apparel Research
Years 1- 3 Demonstration Contract
Final Report
20 September 1999

1. EXECUTIVE SUMMARY

Background. The purpose of Clemson Apparel Research's Demonstration Contract is to develop and demonstrate modern technologies and management practices that optimize the performance of the Department of Defense's Clothing and Textile's (C&T) supply chain. Specific objectives are to (1) eliminate recruit training center (RTC) clothing stockouts, (2) minimize operational and inventory investment costs across the entire supply chain, and (3) level production requirements placed on manufacturers. Clemson Apparel Research (CAR) participates in the C&T supply chain as a model quick-response shirt manufacturer supporting Army and Marine Corps RTCs. CAR also develops and implements integrated improvements for wholesale and retail operations.

Demonstration approach. This paper presents the lessons learned, improvements made, and results obtained during the first three contract years. Year 1 began with CAR forecasting manufacturing requirements for Army Women's Shirts based on point of sale (POS) data from the Army's RTC at Ft. Jackson. Manufacturing initially consisted of special measurement (SM) shirts as requested by the Defense Supply Center Philadelphia (DSCP). Later the manufacturing demonstration shifted to a supply chain demonstration including the manufacturing of quick response (QR) women's shirts for Ft. Jackson. This partnership produced the origins of the "balanced flow" supply chain concepts that were next extended to a commercial manufacturer of battle dress uniforms for the Marine Corps' Parris Island RTC. At the end of Year 3 CAR was manufacturing men's dress shirts for Parris Island and making extensive software improvements in Parris Island's retail operations. CAR's intimate participation in every element of these three supply chains produced many learning experiences that were used to generate large supply chain-wide improvements. By the end of Year 3, CAR developed and implemented a replenishment software module at Parris Island that proved to be the key to achieving all three stated objectives.

Challenges forecasting manufacturing requirements. As a manufacturer, CAR immediately faced the normal challenge of forecasting what to place into production each week so we could fill each requisition by the contractual target date. We attempted to forecast the arrival of requisitions (time and quantity) so we could fill them from finished goods or from work-in-process. We found that POS data alone was insufficient to accurately forecast the arrival of requisitions at manufacturing. Once we obtained recruit accession plans, current inventory status, and replenishment algorithms, we could accurately forecast the normal generation of requisitions. However, our predictions became invalid when Ft. Jackson

introduced policy decisions such as "order early to spend allocated funds" into the process. These policy decisions can not be predicted statistically because they are totally independent of predictable events such as recruit accessions. We determined that the real underlying manufacturing demand was recruit-driven and this demand did not change no matter what policy or ordering parameter changes the RTCs made. It became clear to us that we could achieve significant improvements if we could drive manufacturing and distribution actions from recruit demand plus supply chain-wide inventories rather than from forecasted and actual requisitions.

Challenges managing supply chain-wide inventory buffers. Next, we turned our attention to the inventory portion of the supply chain. A huge inventory buffer existed in many different supply chain segments between the recruit issue process and the initial manufacturing process. A buffer is required to protect the issue process from upstream supply variation and to protect manufacturing from downstream demand variation. However, the existing buffer was so large that the ARN immediately set an objective of reducing it by 50 percent.

The primary cause of most of this large supply chain-wide buffer was a combination of the RTCs' replenishment software and the way the RTCs were using the software. Both RTCs used outdated economic order quantity (EOQ) replenishment systems (see 3.2.5) and set all parameters to maximize inventories. They stocked as much as possible of every NSN because this was the only way they could minimize the impact of the few NSNs that were normally out-of-stock in the wholesale system. Unfortunately, stockage levels and replenishment frequencies are linked in these EOQ replenishment systems. The more that the RTCs stocked, the less frequently the EOQ process generated replenishment orders and the larger the quantities on each order. This, in turn, required huge wholesale inventories to meet the demands of the large, infrequent RTC requisitions. In 1996, DSCP attempted to improve the system by implementing direct vendor delivery (DVD) which had recently become very popular in commercial supply chains. However, DSCP passed the retail requisitions directly to the manufacturers who did not have sufficient buffers in place to react in a timely manner. The extensive problems that this generated highlighted the importance of proper strategic inventory buffer management.

Finally, we observed that the performance measurement system used by DSCP had fully institutionalized these buffer management problems at the wholesale level. Since the wholesale item managers did not have visibility of retail stockage levels, they could only react to, and be measured by, how quickly they completely filled all RTC requisitions. This activated a lot of management and production resources at wholesale and manufacturing on

items that were not currently needed at retail. Items that were actually needed earlier had to wait their turn. This cycle contributed to more stockouts and higher inventories by creating longer supply chains.

Following is our description of the operation of the existing supply chain:

> **To minimize the severe pain from a few anticipated wholesale long-term stock outs, retail item managers maximized stockage objectives and made unpredictable policy decisions to "get ahead" of the system. Their EOQ replenishment systems responded by infrequently generating fewer requisitions for larger quantities, most of which were not needed until well into the future. Since these large requisitions could not be forecasted accurately, wholesale managers had to stock large inventories to ensure adequate coverage. This resulted in huge inventories at retail and wholesale and did not eliminate the wholesale stockouts. In order to minimize these stockouts and fill requisitions as quickly as possible (with items that were not really needed), wholesale item managers passed "expedite" orders to manufacturers. These "expedite" orders caused inefficiencies in manufacturing and extended the production lead times. This cycle fed on itself because longer production lead times extended the supply chain which, in turn, increased inventories and stockouts.**

<u>The Core Problems.</u> We identified two core problems that had to be solved together to break this cycle:

1. **The retail economic order quantity (EOQ) ordering systems batched demand and ordered (requisitioned) very large quantities infrequently.**

2. **Inventories were unbalanced across the entire supply chain.** (This was both a core problem and the results of core problem #1.)

<u>The Balanced Flow Solution</u>. Our solution was to create a software module that used operational parameters and current inventories from all segments of the total supply chain to compute quantities to make and quantities to ship. We ran this software weekly to re-balance the inventories in days-of-supply at the RTCs and within the entire supply chain. Immediately, the out-of-stock problems and expediting disappeared. Later, we split the module into retail and wholesale segments. We replaced the EOQ ordering module in Parris Island's retail system with our balanced flow retail module. This proved to be a very effective and efficient inventory reduction tool for Parris Island. The requisitions generated could be forecasted and filled easily by either the wholesale managers or the manufacturers. We used

the wholesale segment of our balanced flow software to generate manufacturing requirements at CAR. This re-balanced the entire supply chain that, in turn, minimized the risk of both stockouts and excessive inventories.

Balanced Flow Results. At both Ft. Jackson and Parris Island, placing items on the complete (retail and wholesale) balanced flow system eliminated stockouts, reduced wholesale and retail inventories by more than half, reduced manpower requirements, and reduced warehouse requirements.

Critical balanced flow success factors. Implementing the balanced flow concept proved to be the key in meeting the stated objectives. In addition, four associated critical success factors must be addressed if we are to optimize each of the ARN objectives in future efforts.

1. Each RTC must realize they are full partners in the supply chain and that the replenishment actions they take do have a profound impact on the entire supply chain including their own stock availability, operational expenses, and item prices. Ideally, the ordering process would be replaced with a push replenishment process. However, when RTCs do not switch to a push process, they must generate their requisitions in a balanced flow rather than in EOQ-driven batches.

2. DSCP must take the lead in reducing order-ship-time (OST) variation and averages so RTCs can safely reduce inventories below the 30 to 45 day-of-supply levels. This includes minimizing OST system delays, awarding contracts that value short production lead times, and eliminating the few remaining backorders through quick response, flexible production lines.

3. DSCP should create flexible manufacturing capacity to eliminate the few remaining wholesale stockouts. This would eliminate the need for retail managers to maximize stockage of all NSNs in order to reduce the pain of the few, but unknown NSNs that may go on long-term backorder in the future.

4. Retail and wholesale managers should adopt primary supply chain-wide performance measurements that optimize the performance across the entire supply chain rather that just optimizing local processes. These measurements are order-ship-times, inventory turns, expedite requests, and operational costs. The measurement of supply satisfaction should be used with extreme caution as long as infrequent, large-batch requisitions are submitted. Exceptional actions taken to honor these large batch demands result in increased operating expenses, inventories, item prices, and stockouts.

Surge Requirements. An objective of enhancing surge capabilities should be added to the current ARN objectives of no stockouts at minimum costs. As we shorten the supply chain, we take inventories of raw materials out that have historically been used to surge in emergency conditions. This excess will no longer be available and production lead times for raw materials is much longer than production lead times for apparel production.

Manufacturing summary. Prior to this demonstration contract, CAR had established a quick response automated production line consisting of over $2.0M of state-of-the-art loaned equipment. By the end of Year 3, military and commercial shirts were produced on the same integrated line within 3 days and the value of the equipment had grown to $2.5M.

Originally, CAR established a separate manufacturing line of manual machines for producing the different styles of special measurement shirts. All commercial shirts were produced on a line of highly automated machines that required larger changeover times between shirt styles and sizes. Since the military volume was low, approximately three highly skilled, cross-trained operators could assemble the military shirts rather quickly without interfering with the commercial production. The primary challenge for producing the special measurement shirts was the extensive work and time required prior to cutting.

Early in Year 2, we reengineered all of our SM shirt processes. This brought our leadtime down from about 35 days to just over 7 days. We identified the need for an integrated automated system to get under 7 days. Next, we began to construct this system using Microsoft Access and Visual Basic programming. Once this system was operational, we cut additional costs and were able to routinely ship in less than 7 days. We also launched separate ARN projects to make further improvements that eventually reduced the pre-production times to minutes and cut the costs by over 95 percent.

In Year 3, we determined the need to integrate all military shirt manufacturing onto the commercial line and eliminate the separate military line. We requested and obtained a number of waivers to permit us to use commercial templates to reduce changeover times on the automated equipment. By the end of Year 3, we had completely integrated all military quick response and special measurement shirts with our commercial shirts.

Demonstration benefits summary. The primary benefit of the demonstration has been to provide the supply chain perspective of the manufacturer to the ARN partners. Being a real manufacturer drove us to understand the impact of decisions made in other segments of the supply

chain on manufacturing. This enabled CAR to formulate many projects internally and across the ARN that are achieving positive results.

To date most of our manufacturing advances have been in the pre-production areas of special measurement and quick response manufacturing. For example, we have reduced special measurement lead times from weeks to minutes and have significantly improved the C&T supply chain as discussed earlier. At some point in the future, the ARN will turn to the manufacturing floor to further reduce the length of the supply chain. CAR has the model in place and is routinely making shirts within 4 days as compared to the industry standard of 4 to 6 weeks.

2. INTRODUCTION AND BACKGROUND

Purpose: The purpose of Clemson Apparel Research's (CAR's) Demonstration contract is to support the Apparel Research Network's (ARN's) goal of creating customer driven uniform manufacturing (CDUM). Specific CDUM objectives are:

(1) Eliminating recruit training centers' (RTCs') clothing stockouts.

(2) Minimizing operational and inventory investment costs across the entire supply chain. This includes reducing inventories by at least 50 percent.

(3) Leveling manufacturing requirements.

Approach: CAR supports the ARN through research, through a manufacturing demonstration, and through a supply chain partnership with Parris Island Recruit Training Center. CAR conducts independent research, maintains active membership in research committees of trade associations, and conducts research with other ARN partners. CAR demonstrates the results of this research plus other cutting-edge technologies and management practices by operating a fully functional model factory that produces commercial and military shirts. Supply chain research results are demonstrated at CAR, at Parris Island and with other ARN partners.

CAR's research in the first two years contributed greatly to the evolution of the ARN's efforts in ordering and inventory management. The ARN began its approach with a relatively balanced effort with focus groups in development and design, pre-production and production, and ordering and distribution. In Year 2, the ARN realized that the greatest opportunities for meeting the ARN objectives were in strategic inventory management rather than manufacturing or design. The overall ARN focus shifted to logistics through

the formation of a virtual prime vendor (VPV) effort structured to make the most of these opportunities. Working closely with the Program Manager, DSCP, and other ARN partners, the CAR demonstration identified these opportunities, provided the essential concepts, and helped define the generic steps required to implement VPV.

CAR's initial CDUM research and demonstration efforts resulted in three major thrust areas within the CAR demonstration:

1. Manufacturing. The demonstration began with the focus on the manufacturing line and that continues to be one of our three major areas of emphasis, but it is now third in overall priority.

2. Special Measurement Supply Chain. Shortly after the demonstration began, the Defense Supply Center, Philadelphia (DSCP) requested CAR manufacture special measurement (SM) shirts because of their large backorders and their inability to interest commercial manufacturers. These SM shirts became the primary focus of our production line for most of the first year and the associated pre-production work evolved into several very successful independent research efforts that now constitute our middle priority thrust area. We were forced to build efficient automated modules to manage orders, manipulate patterns, and ship garments within required time frames. Our research revealed unacceptable error rates as well as unacceptable delivery times with the existing SM ordering system. The Web-based electronic order form was created to overcome these ordering problems through a separate, but closely associated contract that is fully documented in a report entitled "Clemson Demo Electronic Order Form Final Report." The first three years of the pattern manipulation work is documented in detail in a separate report entitled "Clemson Demo Special Measurement Final Report." We continue to improve the electronic order form and the automated pattern software. Early in Year 3 we implemented the ARN's primary automated production software from Georgia Tech and we have modified it significantly in a modular fashion to minimize our pre-production times and costs.

3. Virtual Prime Vendor. The highest priority thrust area is logistical in nature and has become known as the Balanced Flow Inventory Replenishment System (BIFRS). BIFRS is a supply chain-wide management concept with supporting Web-based software and systems that re-balances the flow of orders up the supply chain and product back down the chain on a weekly basis. It is being implemented in conjunction with other ARN projects as the VPV effort.

This report addresses the development of the VPV balanced flow concept from the beginning of the contract in March 1995 through December 1998. Emphasis is on the lessons learned that supported the development of the balanced flow concept. A separate document is being maintained that describes the operational scenario for the complete VPV effort. Lessons learned are highlighted by italicized sub-titles. Finally, this report also provides the status of the manufacturing line and other demonstration projects as of the end of Year 3 in December 1998.

3. DEVELOPMENT OF THE BALANCED FLOW SUPPLY CHAIN

CAR 's initial focus on manufacturing quickly shifted to the other segments of the supply chain when CAR's capacity was overwhelmed by retail ordering practices. Unlike normal contractors, CAR had the responsibility to identify the source of the problems, develop solutions, and demonstrate the solutions in a complete supply chain. These individual solutions slowly evolved into today's balanced flow concepts, software, and supply chain management methodologies. This evolution of the balanced flow concept and its application is an excellent case study of the unforeseen benefits that can be derived from a manufacturing technology demonstration.

This section reviews the evolution of the balanced flow concept that now embraces the entire supply chain including manufacturing. It is clear that the concept has significant potential beyond the current demonstration for Marine Corps apparel. In fact, it should be at the core of any future C&T system modification – ARN or other. In addition, the balanced flow software that generates manufacturing requirements should be applied to any procurement wherein the government in effect buys production line capacity rather than stocked commercial items. The balanced flow ordering software should be used at retail to replace all DoD ordering processes that are based on economic order quantity systems.

3.1 PREDICTING OVERBLOUSE REQUIREMENTS FOR FT. JACKSON

Ft. Jackson was selected as the initial supply chain partner for CAR because of its close proximity to CAR and because it was involved in DSCP's first efforts to implement a new management practice known as quick response (QR). In the late 80's and early 90's a number of new technologies and needs converged to create a large movement to business partnerships within the textile, apparel, and retail industries.

US textile manufacturers initiated the QR movement to slow the loss of domestic apparel production. Supply chain partnerships were formed to replenish apparel that was sold at retail much faster by using new automation technologies and business practices. These alliances became known as QR partnerships and the primary principle was to use real-time point of sale (POS) data to drive the entire supply chain for faster replenishment and higher profits for everyone. The concept was to stock a small number of apparel items at retail at the beginning of each season, capture individual sales by scanning them into an automated database system shared by all partners, and immediately initiate upstream replenishment based on this POS data. The goal was to limit the number of marked down items and increase the number of items that could be sold at full price multiple times during the season.

CAR's manufacturing demonstration contract began in March 1995 as a continuation of the previous 7-year shirt manufacturing demonstration in which CAR was manufacturing various military and commercial shirts. DSCP had recently initiated its initial QR project at Ft. Jackson by providing software and hardware for Ft. Jackson to use in collecting POS data. While waiting to install the equipment, Ft. Jackson was manually providing POS data on 6 items to DSCP. DSCP was sending this data to manufacturers who were determining if they could use it to accurately predict manufacturing and finished good requirements. The Army woman's overblouse was included in this data and was approved as the shirt for CAR to manufacture for the demonstration. CAR acquired and used this POS data to forecast requisition receipts and launch production of all sizes of the overblouse with an initial production capacity of 50 shirts per week.

CAR then acquired actual requisitions from Ft. Jackson (ones that had been filled from depot stocks or passed to commercial manufacturers for direct shipment) and compared them to CAR's forecasted requisitions. Initially, CAR accumulated production and occasionally shipped shirts to a depot – no open requisitions were sent to CAR and no shirts were shipped to Ft. Jackson. Therefore, there was no real connection between demand and manufacturing.

The original intent of the manufacturing demonstration was to forecast demand using POS data and produce garments to meet this demand with minimum work-in-process and finished goods inventories. The focus was on maximizing manufacturing speeds and minimizing costs of manufacturing with the eventual transfer of the successful aspects of this manufacturing system to defense apparel manufacturers. The following paragraphs show how the focus shifted to the entire C&T ordering, manufacturing, and

distribution system as CAR learned more about the problems and their sources across the entire supply chain.

About the time that CAR's production was getting underway, DSCP asked for help with a backlog of special measurement shirt orders. CAR continued to produce overblouses, but its manufacturing focus shifted to special measurement shirts for most of the first year. The special measurement project is addressed briefly later in this report and by its own separate report.

3.1.2 POS Data Alone is Insufficient to Forecast Demand

CAR completed the research project of using POS data to predict requisition receipts and, like other manufacturers, validated that POS data alone was not sufficient to launch manufacturing. Ft. Jackson used an EOQ ordering system that generated requisitions infrequently for very large quantities of replenishment stocks. We could match the production levels to the consumption levels through the POS data, but could not predict when the EOQ system at Ft. Jackson would generate a new requisition or when it would arrive at CAR. Our finished goods inventories were either unacceptably short or long when compared to requisitions generated by Ft. Jackson.

3.1.3 Recruit Projections, Inventories, and ACIIPS Logic are Sufficient, but...

During this first year, CAR examined the Army's Automated Clothing Initial Issue Point System (ACIIPS) software to learn how it replenished and managed recruit clothing. With an understanding of the logic the ACIIPS program used to generate requisitions and Ft. Jackson's decisions concerning operating and safety levels, we again tackled the problem of predicting the arrival of requisitions. We provided the Ft. Jackson CIIP a fax machine and they occasionally faxed CAR printouts from the weekly ACIIPS report for our research. This included inventory status as well as other logistical data such as requisition status and recruits processed.

CAR found we could very accurately predict the generation of requisitions and the requisition quantities from the ACIIP system once we had complete information. This consisted of (1) on-hand and on-order status, (2) recruit accession schedules, (3) the ACIIPS algorithms, (4) historical demand, and (5) the algorithms to calculate the quantity to place on order. This was totally in line with our experience in the commercial world where the requirements for an efficient QR program are timely POS data, retail inventory levels, and re-supply rules.

However, it became clear later that policy decisions, based on factors outside of the ACIIPS software, could not be predicted and were adding huge artificial variations to item demand. For example, ordering large quantities of

inventory early to use available funds and get a head start on the other RTCs could not be forecasted. In fact, the wholesale system sees this type of surge in demand as normal growth and reacts as if this level of demand will continue!

3.1.4 Recruit Training Centers Must Be Full Partners in Managing the Supply Chain!

If demand can not be forecasted accurately, the results will be stockouts and/or excessive inventories. The only short-term solution to this situation is extremely large inventories. This is why the DSCP had such large inventories in place. It makes no difference to the wholesale supply chain partners how much the retail partners stock, but the methods the retail partners use to order replenishment stocks largely determine the performance of the wholesale portions of the supply chain. The supply chain is a system of processes in which each process is dependent on the performance of the previous process. When requisitions drive the entire supply chain, they must be generated in a manner to optimize the performance of the entire supply chain. Infrequent, large requisitions that could not be forecasted accurately caused the large inventories at retail and wholesale. It became clear that the RTCs had to become active partners in the supply chain; not just the final consumers who thought their stocking and ordering policies had no impact on the performance of the supply chain.

3.2 FROM MANUFACTURING TO A SUPPLY CHAIN DEMONSTRATION

In December of 1995, CAR requested an expansion of the original manufacturing demonstration to optimize the use of modern technologies and management practices across the entire supply chain. This included the receipt of actual requisitions from Ft. Jackson and the shipment of shirts directly back to Ft. Jackson rather than pretending the requisitions were to CAR and later shipping stocks to a depot. CAR received approval in June of 1996 to go live with the new QR demonstration by manufacturing seven sizes of the women's short sleeve shirts for Ft. Jackson.

About this same time, the Army announced a change from the overblouse to a new tuck-in style shirt. The tuck-in shirt was fielded in the fall of 1996 and Ft. Jackson was at a routine re-supply position by the end of 1996. CAR was required to wait until the pipeline was filled with the new shirts because of our small production capacity. We were permitted to begin the full-up QR demonstration in January 1997 by producing Ft. Jackson's actual requirements for the three smallest and four largest shirts. Our intention was to average about 100 QR shirts per week. While waiting a year to begin the supply chain demonstration, we had the time to learn a lot more about

the entire C&T supply chain. This knowledge would prove to be extremely valuable later to the overall ARN effort.

3.2.1 The Army Orders up to One-fourth of Its Annual Consumption On 1 Day Each Year!

A significant problem occurred in May of 1996 that highlighted the problems caused by large requisitions. The Army's ACIIPS program requires an updated recruit forecast the first working day of each month. ACIIPS generates requisitions according to on-hand inventories and the number of recruits scheduled to arrive during the first month beyond the current month. Since the summer surge begins in June, this is the first time each year that ACIIPS routinely orders for the summer surge. Ft. Jackson inflated the numbers and ordered $11M or about one-fourth of its annual demand the first day of May to be sure they would have sufficient stocks for the summer surge beginning in June. This had always been the normal procedure for the Army RTCs. DSCP had always filled these requisitions from their large depot buffers. However, something was very different this year a few process steps up in the supply chain.

3.2.2 Take the Buffer Away and See What Happens!

Beginning in October 1995, DSCP placed most new contracts on direct vendor delivery (DVD) to reduce distribution costs, to improve shipment accuracy, and to improve order-ship-times. Customers were linked directly to these manufacturers so that newly arriving requisitions were automatically placed directly onto delivery orders. The result was that depot inventories were effectively removed from the supply chain for DVD items placed on these new contracts during the first half of FY96.

The contractors did not have sufficient buffers of finished goods in place before the May requisitions hit the system. They had no knowledge of the need for such large inventories, no data or systems to forecast the May requisitions, nor sufficient capacity to build large inventories. They could not possibly respond in a timely manner because of their long production lead times and the size of the orders. Stockouts and backorders increased to an unacceptable level.

No warnings were available until shortages surfaced at the RTCs. Once DSCP tied a requisition to a contract, they sent the ordering RTC item manager a status that the item would be delivered within the number of days required by the contract. Neither the contractors nor DSCP had any capability of providing additional status.

The retail item managers were not aware that anything was wrong until their safety level flags began to appear and they began to run out of stock.

They called the wholesale item managers asking the status of their orders. The wholesale managers had to call the manufacturers to get the status. It was clear that many items would be unacceptably late so the retail managers requested their requisitions be filled from stocks in the depots. This could not be done because the original requisitions were now assigned to contracts and could not be withdrawn. The retail managers had to send additional high-priority requisitions to buy these same items from the depots. To make matters even worse, this was near the end of the year and funds were not available to double order everything. These RTC stockouts were not resolved until early fall and it was much later before the wholesale and manufacturing sections of the supply chain recovered.

3.2.3 Direct Vendor Delivery Does Not Work Without the Properly Sized Buffer!

In summary, Ft. Jackson tied up scarce funds ordering many more garments than they needed, stockouts increased, expediting increased, operating expenses went up across the supply chain, and inventory investments increased. There must be an adequate buffer of inventory between the consumers and the manufacturing lines. DSCP, in effect, removed their portion of this buffer from the automated supply chain when they passed requisitions directly to the manufacturers. The manufacturers did not have sufficient data to predict the arrival of the requisitions nor did they have sufficient capacity or finished goods to fill the requisitions within the required time frames. Shortages resulted and operating expenses increased as the RTCs' high priority requisitions were managed off-line. Expediting skyrocketed in manufacturing. There was total dissatisfaction and frustration across the entire system. CAR realized there had to be a better way and began to dig deeper into the ACIIP system to determine why such large orders were placed each year.

3.2.4 The ACIIPS Software <u>and</u> the Way it is Employed are the Problem

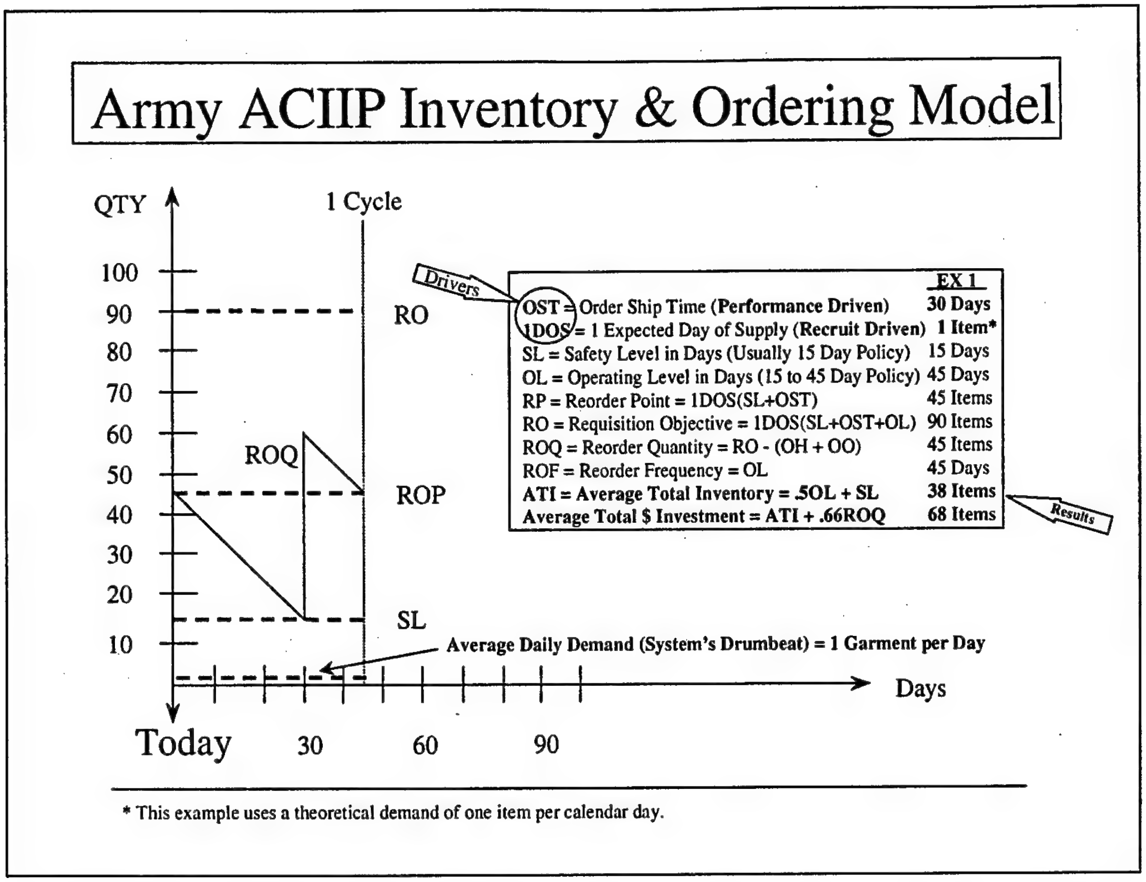
During the summer of 1996, CAR came to fully appreciate and understand the inventory and stock-out problems at Ft. Jackson. Historically, the retail replenishment system was well designed and functioned properly when inventory investment was of little concern, sufficient stocks were on-hand in the depots, and requisitions were placed at least 30 days prior to the time of consumption. Stockouts occurred infrequently when contracted production ended unexpectedly or new contracts were awarded late. These low stockout rates would have been the envy of any commercial apparel system. However, since every recruit must have every item, the pain of a few stockouts caused Ft. Jackson to maximize their stockage objectives on every item in every possible way to cover DSCP's potential problems. This resulted in both Ft. Jackson and DSCP carrying huge inventories at large inventory investment and operational costs. Moreover, an unacceptable level of stockouts still existed!

Ft. Jackson's inventory investments were huge at well over 125 days of supply and their stockout level of almost 3 percent was totally unacceptable. When we analyzed their inventories, we found the primary reason for the large total inventories and large stockout rate was that Ft. Jackson's items and mixes of sizes within an item were not balanced. They had extremely long supplies of many items and sizes and were out of stock for a few others. Usually, the wholesale stockage in-balances mirrored the retail in-balances.

3.2.5 Ft. Jackson, Using ACIIPS, Invests in 68 Items to Support 1 Item Issued per Day!

In fact, our investigation revealed the retail system was caught in a vicious cycle in which wholesale stockouts and slow replenishment performance (order-ship-time) drove retail stockage requirements higher. The higher stockage requirements drove less frequent ordering. Less frequent ordering drove larger orders. Larger orders, whether passed directly to manufacturers for direct delivery or not, drove slower replenishment. The following chart shows the effect of the Army's EOQ replenishment system on its own internal inventory and cash requirements. In summary, Ft. Jackson had to carry in inventory an average of 38 items and invest in an average of 68 items to support a demand of one item per calendar day!

Chart 1 – Army ACIIPS Inventory and Ordering Model



This type of economic order quantity (EOQ) replenishment system was developed years ago when it was very costly to manually conduct inventories and fill out requisitions. Initially there was a parameter for these costs in the reorder equations and managers balanced local operating expenses of inventorying and ordering with their storage capacity and available ordering funds. Within the military there never was any need to consider inventory investment costs. Over the years the costs of conducting inventories and filling out orders dropped out of the systems, but the reorder point logic (ROP) remained. Today, with computers there is virtually no cost associated with placing a requisition, but the systems still operate as if this cost is a major factor.

Chart 1 also introduces the day-of-supply (DOS) concept that later became a primary part of our balanced flow system. In developing Chart 1, we had to show a benchmark demand against which we could compare the corresponding actions of the ACIIPS. We decided it would be easy to understand the average demand of one item per calendar day for the entire year. We labeled this one item per day the one day-of-supply or "1DOS" forecast of demand. We later defined the number of days of supply of an item based on this 1DOS consumption rate as the annualized days of supply or "ADOS."

3.2.6 Blind Managers and A Few Wholesale Stockouts Create Big Problems

Once we understood that Ft. Jackson's large orders were actually increasing both stockouts and inventories across the entire supply chain, we wanted to know what would be required to break this cycle. Smaller orders flowing up the supply chain would improve the problem significantly, but there had to be other sources of the initial stockouts that created the chain of events in the first place. These sources also had to be identified and removed.

The RTCs were carrying well over 100 days-of-supply and still had stockouts. Our investigation revealed that there were at least four other origins of these stockouts:

1. Incorrect retail inventories caused orders to be placed late. This occurred infrequently at Ft. Jackson.

2. Wholesale item managers could not see supply chain assets at retail so they could only rebalance the wholesale portion of the supply chain. This caused particular problems with items in such low demand that their production lines could not always be hot and flexible.

3. Requisitions were not filled expeditiously even when wholesale stocks were available. This occurred frequently, but was not responsible for months of delay.

4. **A very few long-term wholesale stockouts were the key to the entire cycle of large RTC inventories that, in turn, produced even more stockouts and inventories.**

Wholesale item managers attempted to balance wholesale inventories in months of supply as best as they could using available tools while contracts were active. However, many forces acted to create in-balances – especially the large, infrequent orders from the RTCs for the items in lower demand. The administrative workload of modifying contracts was also a burden that often prevented re-balancing, especially when all sizes were above the item manager's comfort level. Emergency buys of "fill-in" sizes were also difficult because of the administrative requirements and the lack of contractor interest. The result of this was that a few sizes would go to zero balance well before a new contract could be justified. Contractors would not bid on small contracts for a few "fill-in" sizes and DSCP could not afford to commit scarce funds for normal contract quantities. Therefore, a very few sizes of some items would be out of stock in the wholesale system for sufficient time to cause a few long-term retail stockouts. There used to be a solution to this problem, but it went away when the DSCP Factory closed in 1993.

3.2.7 A Surgical Solution Could Generate Large Performance Improvements

One of the many roles that the DSCP factory served was to deliver relatively small quantities of these "fill-in" sizes of all items before the wholesale and retail systems ran out of stock. The factory carried all the necessary raw materials, they could be directed to make the items quicker than contracts could be awarded, and they did not tie up large funds by demanding large orders. As we learned later (see Section 3.5.3) the benefits from a small, but responsive manufacturing capacity can have supply chain-wide benefits that go way beyond the obvious direct logistical benefits.

The retail managers know their mission is not tolerant of stockouts. When they have an outage and do the research for the cause, they normally find corrective action has been taken on that particular item and they really do not need to carry extra protection. However, when retail item managers consider how much inventory to carry in the future for all items, they can not predict the few NSNs that will suffer from long-term wholesale stockouts. Therefore, they must carry as much of <u>every</u> NSN as possible to buy buffer time for those few NSNs that will become long-term problems. Reestablishing this type of capability today could really improve the confidence in the supporting supply system from the perspective of the retail item mangers. This would clearly result in a small improvement in retail stockouts, but a large reduction in inventory investment.

3.2.8 Small Demand for Women's Items creates BIG Supply Chain Problems

Small demand is the primary reason there are more stockouts with women's items than with men's items. The demand for these items is so small that months of demand must be placed on contract to interest manufacturers and production of each size is usually completed in a few weeks at most. These items, unlike large-demand items, do not enjoy continuous hot production lines under open contracts. When that first size runs out, there is no contract to modify and there is no DSCP factory to call upon. In addition, it often takes longer to get these items on contract because either no one bids or the manufacturer is new and has start up delays. We learned that it is even more important for these items that all sizes be as balanced as possible in the supply chain when the production lines go cold. There is no possibility of re-balancing or eliminating stockouts for months until the next contract creates a hot production line.

Ft. Jackson could only react by stocking as many of every item as possible to protect against these few long-term wholesale stockouts. This, in turn, led to the large requisitions and the vicious cycle described earlier. It became clear that the ultimate solution had to include total asset visibility, balanced inventories, a flow of orders, <u>and</u> the elimination of these relatively few wholesale stockouts.

During the summer and fall of 1996, CAR manufactured a small number of men's and women's shirts for Ft. Jackson primarily to keep the manufacturing line operating. We had great difficulty filling these requisitions in a timely manner because of the large quantities per requisition. We defaulted to a system of frequently asking Ft. Jackson how many they really needed and sending partial shipments to cover these needs. We knew we were experiencing exactly the same order fulfillment problems as all of DSCP's contractors who were shipping DVD shipments to the recruit training centers. CAR also learned firsthand the negative impact of these large orders at American Apparel, Inc. who was a major producer of hot weather battle dress uniforms (HWBDUs).

3.2.9 American Apparel has Problems Filling Hot Weather BDU Requisitions

During 1996, CAR and Georgia Tech had an Air Force contract to install a real-time system in the American Apparel plants and conduct research on distributive manufacturing controls. While conducting this research, CAR again saw firsthand and in detail the problems a manufacturer has with large, infrequent requisitions. As before, the arrival of the requisitions was not predictable and the quantities were overwhelming as compared to the manufacturer's short-term production capacity. American's capacity was more than sufficient to meet the demand, but American's production lead-time was insufficient to fill an acceptable percentage of the requisitions by the required dates. While making 30,000 BDU shirts per week, American actually had over 50,000 HWBDU shirts in finished goods inventory, and was frequently shipping late.

Unlike CAR, defense contractors are reluctant to make partial shipments because of tracking problems and the risk of delayed payments. They shipped complete orders and often had to wait their complete production lead-time, which was already extended because of expediting. This expediting was requested by DSCP item managers who were trying to solve short-term backorder and stockout problems at the RTCs. We learned that this whole process actually increased the stockout levels and inventory investments at Ft. Jackson as well as costs at American Apparel and all the other manufacturers in the longer term.

3.2.10 Recruit Issues are Very Predictable; Requisitions are not Predictable at all!

CAR learned another important lesson in December of 1996 while manufacturing shirts for Ft. Jackson. We caught up with all orders for the first time in a year and had to decide what to produce to keep the line going until new requisitions arrived in January. We based our decision on previous requisitions from Ft. Jackson and decided to make a particular size because the quantity recently ordered had been very high. In a visit to Ft. Jackson in

January, we discovered the previous requisitions for this size mistakenly vastly overstated actual requirements. Now that we had made even more, there were several thousand days of supply in our supply chain! The lesson learned again was that manufacturing requirements must be based on retail issues and not on the RTC's order generation. Recruit issues are very predictable; requisitions are not predictable at all.

3.2.11 Recruiting Commands Strive to Minimize Clothing Demand Variations

The reason that recruit demand is by far more predictable than the receipt of requisitions is based in the fact that the RTCs operate according to a budget for all their resources. This budget covers every aspect of basic training including classroom seats, instructors, drill sergeants, ammunition, ranges, food, clothing, and overhead. The driving force behind the budget is the recruit forecast. The recruiting commands adjust incentives and actions according to how they are doing in meeting this forecast and filling classes. This adjustment of resources actually results in minimization of the variation from the forecast. Much more variation is inherent in the batching of demand for the generation of requisitions and in the policy decisions that have nothing to do with recruit demand.

3.3 THE SUPPLY CHAIN DEMONSTRATION BEGINS

In January of 1997, CAR began the complete QR demonstration as requested in December of 1995. Initially we tried to fill Ft. Jackson's requisitions as they arrived and ship them within the same time frames, as other DVD contractors were required to do. Immediately we encountered the expected order fulfillment problems. The annual average weekly demand for our seven sizes of women's shirts was only 84 and our "contracted" capacity was 100 shirts per week. However, we could not possibly fill individual requisitions for quantities of up to 400 shirts in a timely manner.

While using all available capacity to complete one large order for one size shirt, we were getting behind on other orders for other sizes. At the same time, Ft. Jackson only really needed a small part of some orders, but they did not need the vast majority of any order. They placed requisitions infrequently and in large batches and we had to expedite manufacturing and ship small, critical shortages constantly to meet the need of the recruits. We realized we were chasing the wrong thing! As a manufacturer, we had to find a better way because making 100 shirts a week should have been no problem at all. We could not revert to a huge buffer as this would solve the problem, but our mission was to eliminate stockouts <u>while</u> reducing total inventories by at least 50 percent.

3.3.1 *"It is not my Problem!"*

We tried without success to get Ft. Jackson to order very frequently in small batches. They felt that they should not do this for three reasons.

1. Filling orders within the standard timeframes was the responsibility of the wholesale system and was not their problem.

2. If they ordered more frequently, they would have to process more receipts and they did not have the resources to do this.

3. Finally, they did not believe their ACIIP system would permit the modifying of parameters for selected items. They felt this would have to be done for every item if it were done for one. They did agree to drop their Operating Level from a maximum allowed 45 days of supply to 40 to see what improvements would result. No improvements were evident.

We later compromised by routinely shipping partial shipments against their large orders. This allowed us to create a flow of replenishment stocks and manufacture the quantities and sizes needed with our capacity.

3.3.2 *The Size of the RTC Inventory and the Frequency of Ordering must be De-linked!*

Why did Ft. Jackson order in this manner? As discussed in Section 3.2.5, the ACIIP system is an economic order quantity system that uses reorder point (ROP) logic to determine if a new order should be generated. <u>ROP logic adds variation to the supply chain</u>. The higher the stockage objective the less frequently the need to place an order. The less frequently requisitions are generated, the larger the orders and the less predictable they are. In other words, the frequency and size of orders are tied to the amount of stockage. The fear of running out of stock caused Ft. Jackson to set all parameters to maximize this problem. This is normal because the only short-term solution to stockouts is to stock more. The amount of inventory on-hand at Ft. Jackson should not have any direct impact on the wholesale system, but it was clear that the manner in which they placed their orders on the wholesale system did have a profound impact. It became clear to CAR that we had to de-link the size of the retail buffer and the frequency of ordering to meet our ARN objectives of no stockouts, minimum inventories, and level manufacturing.

We began receiving weekly faxes of inventory status reports from Ft. Jackson and obtained approval to ship partial orders routinely. We were in the low-demand part of the year (January) so we could build up a small finished goods inventory and re-balance each of the seven sizes in days-of-supply across the entire supply chain from work-in-process forward. Ft. Jackson further agreed that they would be satisfied if CAR could maintain a 35 day-

of-supply at the RTC. We then used the weekly inventory status to determine how many to ship and how many to make each week for each size. By ignoring requisition quantities and shipping actual needs as partials, we broke the link between Ft. Jackson's stockage objectives and ordering frequencies. Immediately, the low-inventory emergency telephone calls and all expediting ceased. This system quickly eliminated stockouts, leveled manufacturing requirements and eventually reduced our total demo supply chain inventories by well over 90 percent compared to the normal system.

3.3.3 Retail Bulk Inventories can be By-passed!

Our vision of future state possibilities was expanded when we observed how Ft. Jackson was handling our weekly shipments. Their normal inventory flow included shipment receipt, storage at a remote bulk warehouse, movement to back-up storage in the RTC, and finally movement to the issue lines. They soon stopped all this repetitive handling of our items. They just received them and moved them directly to the issue bins. Since they were getting exactly what they needed weekly, they could replenish their issue bins very efficiently in this manner. We established the elimination of bulk warehouse processing as a future goal to further reduce 2 to 3 days of inventory requirements and reduce local operating expenses.

3.3.4 The Origins of Balanced Flow Software

We set up an Excel spreadsheet to do the repetitive calculations and simply loaded it each week with the data from Ft. Jackson's fax. This was actually the origin of today's BIFRS software. A copy of a December 97 version of the spreadsheet follows in Chart 2. A copy of the associated management chart is at Chart 3. The spreadsheet contains all the data required to compute quantities of each size to ship and manufacture in standard unit pack quantities. CAR, however, had to ship and cut in "eaches" rather than standard unit pack quantities because of our small capacity and the small demand per NSN. The chart shows the goals for Ft. Jackson and the entire supply chain in days of supply for each of the seven sized shirts.

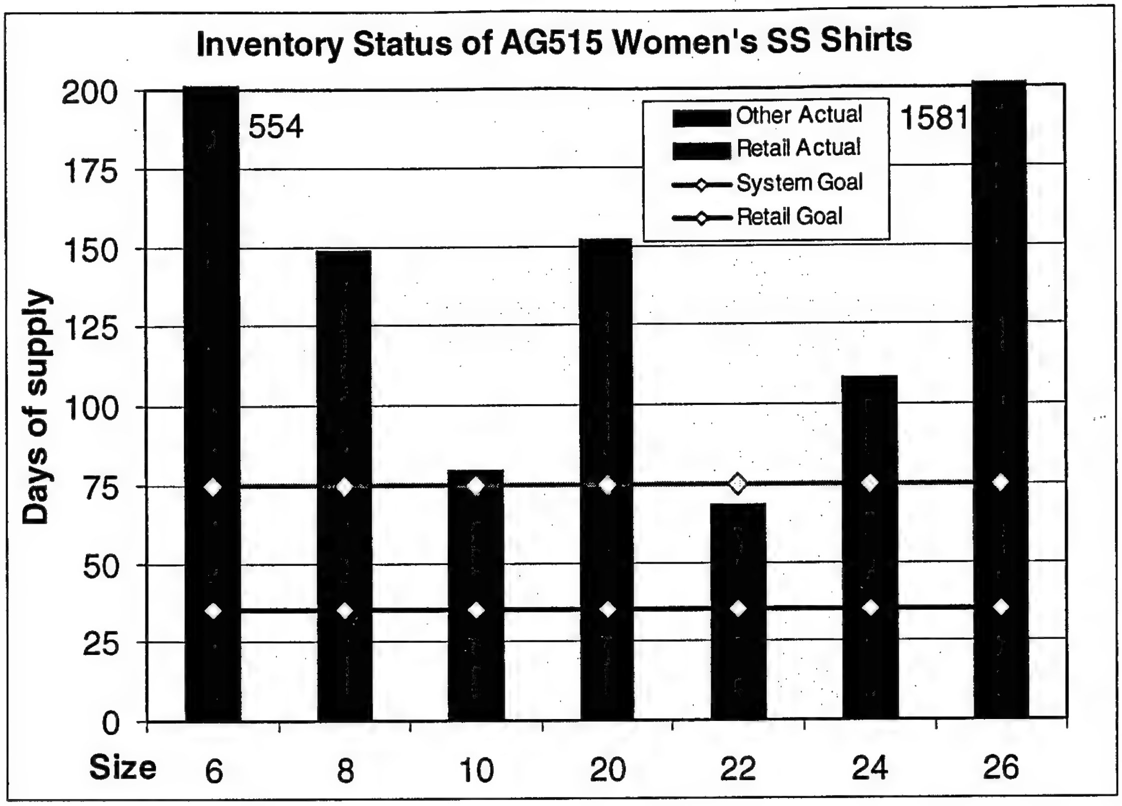
Following size 10 across in Chart 2, we see 35 shirts (7 days of supply) were used the week of 24 November; 217 shirts (43 days of supply) are on-hand; 448 are due-in; and nothing is intransit. We are not required to ship any against the 448 on order the week of 2 December because 43 days of supply are on-hand. However, we need to ship 22 of size 22 and that will cover immediate needs as well as the 7 days of expected consumption next week. Size 10 finished goods contains 182 shirts or 36 days-of-supply; there is no work-in-process; and the entire system contains 80 days-of-supply. The contract requires the production of 84 shirts per week so 84 will be launched into production. If we launch 56 size 10s that will be 4 days-of-supply and we will have 84 days of this size in the supply chain. If we launch 28 of size 22

we will have this size at 86 days-of-supply. The production for next week will be 84 shirts and it will push the two sizes in lowest supply up to about 84 days-of-supply. All the other sizes will drop by about one week's average consumption during the next week.

Chart 2 – Balanced Flow Worksheet for Ft. Jackson Women's Shirts

Shirt, Women's AG415 SS											Schedule Week Begins:			1-Dec		Wk #:	9
Primary PGC:		02281		CIIP Input in dark Blue				Goals:	RTC	Depot	DAM		Bus. Case:		Qty	Value	
Sub PGC:				DAM Input in Light Blue				SL:	35	0	14		Excess Inv:		1861	21,681	
Primary LN:		00012		Computations in Black				SOL:	0	0	#######		Unbal Inv:		71	828	
Substitute LN:		12a		Off Target in Red				IT/WIP:	5	0	7		Total Excess:		1932.08	22,509	
				Ignore in Orange				Total DOS Goal This Wk:			#######		% of Inv Goal:		#######	#######	
Cost:		11.65															
QUP:		50											New Production Requirements				
													Qty to Schedule This Week:				84
	RTC Activity and Status Input					Intransit Inv		Ship	DAM FG INV		DAM WIP INV		Seek min DOS balance of:				84
SIZE	Used Wk of:	DOS Used Wk of:	TQ OH	TQ DI	RTC DOS	Intran RTC Inv:	Intran RTC DOS:	Ship Qty	FG Qty	FG DOS	WIP Qty:	WIP DOS:	System Wide DOS:	Qty for min balnce	Make Qty:	Make in Full QUP	System DOS Actual:
Size	24-Nov	24-Nov	1-Dec	1-Dec	1-Dec	1-Dec	1-Dec	2-Dec	1-Dec	1-Dec	1-Dec	1-Dec	1-Dec	1-Dec	2-Dec	1-Dec	8-Dec
6	0	0	311	0	547	0	0	0	180	317	0	0	864	0	0	0	857
8	7	3	124	0	53	0	0	0	229	98	0	0	152	0	0	0	145
10	35	7	217	448	43	0	0	0	182	36	0	0	80	56	56	56	84
20	25	8	162	304	49	0	0	0	359	108	0	0	157	0	0	0	150
22	11	20	0	44	0	0	0	22	23	42	0	0	42	27	28	28	86
24	0	0	19	20	87	0	0	0	6	28	0	0	115	0	0	0	108
26	0	0	35	0	1581	0	0	0	2	90	12	542	2213	0	0	0	2206
Blank	0	#DIV/0!	0	0	#DIV/0!	0	#DIV/0!	0	0	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!		0	#DIV/0!
Totals:	194	16	868	816	72	0	0	22	981	82	12	1	155	#DIV/0!	84	84	155

Chart 3 – Balanced Flow Management Chart for Ft. Jackson Women's Shirts



When we made our initial calculations of how much to make and how much to ship to rebalance inventories, we were forced to address three additional parameters. First, we had to define in mathematical terms the meaning of balanced inventories. Next, we had to include the seasonal nature of recruit demand in our supply chain inventory objectives. Finally, we knew forecasting was a major source of error and variation, but we had to deal with it so we could have items ready for issue when they were demanded. Our first efforts to address these parameters are in the above worksheet. However, each of these parameters is addressed in detail later in Section 3.6.6 through Section 3.6.10 after the balanced flow concept is fully developed.

3.3.5 The Two Components of a Supply Chain and their Significance

CAR's manufacturing line management expertise was extended to the complete supply chain. Just like a manufacturing line, a supply chain consists of processes and inventory buffers. The processes add value or move the product down the supply chain. There are inventory buffers between each process holding items waiting to be processed and there is also inventory at or on each process. In our demonstration supply chain, the first inventory buffer was unreleased orders at CAR and the first process was CAR's scheduling. The last buffer was the inventory on Ft. Jackson's issue line and the last process was the recruit clothing issue. The primary opportunity for improvement is in the management of the inventory buffers because a

product spends over 99 percent of its life generating interest expense in these non-value-added buffers. These are the "TQ-OH," "Intransit," "FG Qty," and "WIP Qty" supply chain segments shown in Charts 2 and 3 above. If we can eliminate half of the time that an item spends in these buffers, we can cut the total inventory in half and cut the leadtime in half. Stated in other words, this is the way to double the inventory turns per year without redesigning any of the processes! This was what we did for Ft. Jackson and it became the focus of our future demonstration efforts.

3.3.6 DSCP puts The Buffer Back Into The Supply Chain

The balanced flow system for Army women's shirts at Ft. Jackson operated through Year 3 with no problems at all. It was slowly reducing and balancing inventories as anticipated until May of 97. As previously discussed the Army's ACIIP system generates a large surge of orders the first day in May. Again, as in May of 1996, Ft. Jackson ordered huge quantities of all items on 1 May 1997. However, this time DSCP captured and filled these requisitions directly from the depot system to avoid the DVD problems they had during the previous summer surge. This inadvertently included CAR's seven shirts and drove the demonstration's supply chain inventories to well over 200 days of supply. This inventory was consumed slowly over the next year. However, the balanced flow system had demonstrated the steady-state capability of eliminating over 90 percent of retail and wholesale inventories, bypassing the depot system to reduce surcharges, and leveling manufacturing to minimize item costs.

3.4 BALANCED FLOW IS IMPLEMENTED FOR PARRIS ISLAND HWBDUs

In February of 1997, the ARN decided to team with the Marine Corps for a complete supply chain demonstration. The decision was made to team CAR with Parris Island and to expand the demonstration to the hot weather battle dress uniform coats (HWBDUs) being manufactured for Parris Island by American Apparel Inc.

This demonstration was put in place through an improved Excel spreadsheet application in June of 1997 and it ran through January of 1998. The individual supply chain objectives were defined as 66 days-of-supply (DOS) in the primary buffer at Parris Island, 14 DOS intransit, 45 DOS in a special wholesale account at Albany Depot, and 42 days of production lead time at American Apparel. Thus, when summed, the collective objective was 166 days of supply for the entire supply chain. Data was collected weekly by fax from Parris Island. Production requirements to rebalance the supply chain were computed weekly and provided directly to American Apparel by Email and formally as EDI delivery orders through DSCP. Suggested replenishment

requisitions were computed weekly and faxed directly to Parris Island. Thus, for the first time, we were able to re-balance RTC inventories with their own requisitions. The Excel spreadsheet was soon followed by a more efficient and robust Access Relational Database supported by Visual Basic Programming.

This new balanced flow software was named the Balanced Inventory Flow Replenishment System (BIFRS) and originally consisted of two integrated outputs. The primary output was the quantity of each size of the HWBDUs for American Apparel to put into production each week. This was held constant at 2,700 coats as this was the annual average weekly consumption by Parris Island. Only the size mix changed each week. The secondary output was the quantity of each size of the HWBDUs for Parris Island to order each week to balance its inventory at 66 DOS.

This was a test with very aggressive objectives considering that Parris Island had approximately 123 DOS on-hand versus the new goal of 66. In addition, the wholesale stockage policy was 135 DOS rather than the demo goal of 45. No attempt was made to change American Apparel's standard production processes to shorten its leadtime of 42 days.

3.4.1 It Could not get Any Simpler than This!

Within 6 months, 12 of the 22 HWBDU shirts were reasonably balanced near the supply chain's goal of 166 days of supply and the RTC's goal of 66 days of supply. What we observed happening was very profound. As sizes came into balance across the supply chain, weekly ordering generated requisitions according to the tariff and weekly manufacturing requirements were also multiples of the tariff. It could not get any simpler; each week we issued and made the tariff of sizes adjusted for the number of recruits processed.

It also became clear to CAR that the supply chain could actually operate with less than 60 DOS once everything was in place and operating routinely. The essential requirements were real-time total asset visibility, a balanced flow of orders and product, and short, predictable order-ship-times.

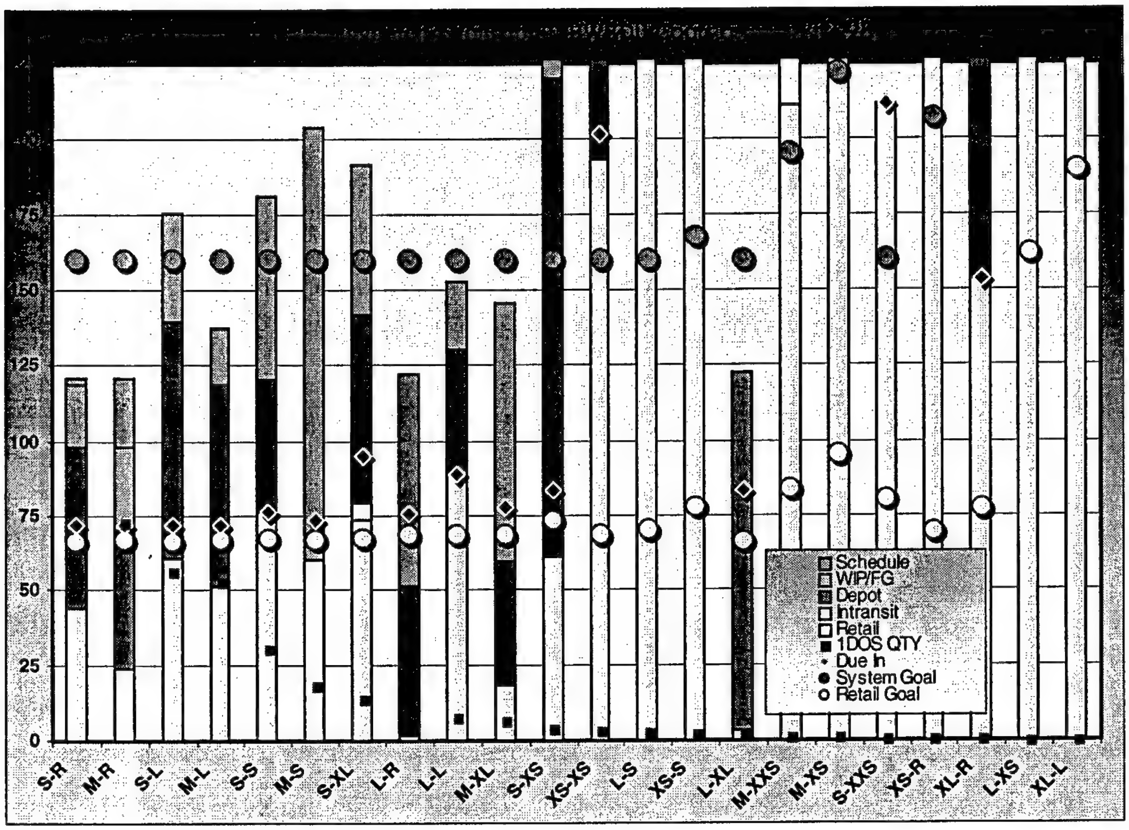
3.4.2 Hot Weather Battle Dress Uniform Shirts Demonstrate Huge Savings

The balanced flow concept immediately eliminated stockouts and, within 6 months, it reduced retail inventories by $200,000. Another 27 days of supply or $262,000 remained in long supply in the other 10 sizes for <u>a potential total retail inventory reduction of over $450,000 for this one item</u>. There also was a theoretical wholesale reduction of over $2M and no value was put on achieving the primary objective of eliminating retail stockouts. In addition, the manufacturer stated that leveling the demand for this one customer only affected 8% of his weekly capacity, but it had a tremendous settling affect on

his entire manufacturing operation. It was so successful that a decision was made to expand it to all bag items at Parris Island during Year 3.

Following is the final management chart from this demonstration. A number of improvements can be noted as compared to the previous Ft. Jackson Management Chart.

Chart 4 – Management Chart for Parris Islands HWBDU Supply Chain



This chart shows the RTC DOS stockage goals for each shirt as a yellow circle and the entire supply chain goal as a green circle. The targets are not the same for each NSN because initial goals are rounded up to full cases. The most frequently demanded sizes are on the left and the least frequently demanded sizes are on the right. One DOS is indicated by the location of the square marker. The light green bars represent the "to schedule" DOS and level 4 NSNs that are in shortest supply at 120 days of supply by using the capacity that is available for this week. An NSN in perfect balance would have the yellow bar touching the yellow target and the top green bar touching the green target.

Our intention was to provide this chart to all three essential managers of the supply chain each week in real time over the Internet. Therefore, the chart was designed to visually highlight all potential problems within the supply chain so the appropriate manager could immediately take corrective action. The retail manager can see the status of each NSN and the combined status of all open requisitions. The wholesale manager can see problems within any segment of the chain. In addition, they can see how well the current production capacity is supporting the supply chain targets. Finally, the plant scheduler can see which sizes should be put into production next and with what urgency for completion.

3.5 VIRTUAL PRIME VENDOR SUPPLY CHAIN IS APPROVED FOR PARRIS ISLAND

The success of this expanded manufacturing demonstration of the HWBDUs led to the FY 98 virtual prime vendor (VPV) demonstration project between the Marine Corps' Parris Island Recruit Training Center, CAR, and the manufacturers of Parris Island's recruit clothing. The ARN maintains an overall VPV business case to justify the expenditures of each of the individual ARN VPV projects. The CAR-Parris Island portion of the ARN VPV Business Case shows conservative potential savings of $20M ($4M retail and $16M wholesale) over 10 years for inventory reductions at Parris Island and its supporting share of the wholesale inventories.

The BIFRS software was tested in 1997 and items were added between March and June of 1998 for the ordering portion of BIFRS only. BIFRS appeared to be working well, but Parris Island did not have sufficient confidence in the accuracy of their MUMMS inventories to risk an attempt to draw inventories down during the summer surge. It was not until the beginning of Year 4 that that Parris Island was comfortable with the accuracy of MUMMS to launch the drawdown. The ARN made the decision in the summer of 1997 to employ a commercial company to extract all required data from the military systems and operate a central database to support BIFRS and several other needs. The implementation of BIFRS for manufacturing was put on hold pending the availability of all the required data from this database.

By June of 1998, it became clear to CAR that BIFRS needed to be split into two parts. A BIFRS-W (Wholesale) module was created to compute the manufacturing requirements for ARN Marine Corps shirts that CAR was manufacturing. A BIFRS-R (Retail) module was created to compute the replenishment quantities for Parris Island as a replacement for the EOQ-based replenishment module of MUMMS. Parris Island transmitted

electronic copies of its daily MUMMS Transaction Files to CAR and we used the on-hand balances and due-ins to run BIFRS-R daily. Once a week the replenishment requirements were sent to Parris Island in "AOA" MILSTRIP requisition format. The item managers reviewed this file, made adjustments if required, and Parris Island sent the modified file directly into SAMMS through ASCOT. Parris Island then converted this file from "AOA" requisitions to "AOE" requisitions and ran it through MUMMS to establish due-ins for each requisition.

For several months CAR successfully ran BIFRS and manufactured end-of-tariff men's dress shirts for the Parris Island and San Diego RTCs. Once the weekly running of BIFRS became routine, we decided the BIFRS-R module should be installed at Parris Island to take CAR out of the daily loop of data transmissions. This was accomplished in November of 1998.

3.5.1 Scanning NSN Bar Codes Slows the Recruit Issue Process

After much debate, Parris Island and CAR decided to forego capturing recruit clothing issues at the NSN level. CAR argued that this is the only way to acquire, in a timely manner, the quantity of each NSN issued. Parris Island argued that it is inefficient and impracticable to use bar codes to capture the issue of individual items to recruits. Parris Island's overriding priority is to issue recruit clothing quickly. We finally decided the most efficient way to do this is to assume every authorized item will be issued and then capture only what is still due the recruit. Parris Island now creates a temporary issue file for each recruit showing an issue of every item at the item level (not the size or NSN level). During the issue process, only shortages are captured and they are captured at the size level to be able to get the correct item to the recruit later. This means Parris Island has to use detailed NSN accounting for bulk storage and convert to cash accounting when an item is transferred to an issue point. Their retail system was designed to operate this way as an alternative to detailed accounting all the way to the consumer.

CAR now uses the movement of items from bulk storage to the issue points to determine the size tariffs and replacement requirements. This is a very acceptable substitute for actual detailed issue data. We have reached the optimum performance for the entire system. This is the fastest possible way to process recruits, operational expenses are minimized, and the balanced flow system focuses on the inventories in bulk storage as an acceptable substitute for retail consumption.

3.5.2 Scanning Bar Codes Replaces Manual Data Entry At Parris Island

When CAR first documented the process flows at Parris Island, we saw significant opportunity in transitioning from manual data entry to scanning and electronic data entry. Parris Island had old scanning devices that had

been provided by Albany, but had never been activated. The accompanying technical data was out of date and incorrect in its description of the operation of the devices. However, we were able to re-map the circuits and program the scanners. We created programs for receiving, Phase 1 and Phase 2 issue line replenishment, and taking physical inventories. As Parris Island implemented scanning, operational costs went down, inventory requirements were reduced, and improved data quality was improved.

The concept was developed to scan empty cases (or empty bin labels) on the issue lines to record replenishment requirements. These requirements are then filled by new receipts into clothing or out of bulk storage. At bulk storage picking lists are automatically produced. Once stowed, the replenishment items are deducted from one issue point and credited to the other. Receipts are scanned and storage directions are automatic – the cases can be sent directly to replenish an issue line rather than going through bulk storage. Quarterly inventories can now be taken much more efficiently because inventories are much lower than before and scanning is faster than manual counting. Parris Island's implementation of scanning continues into Year 4.

3.5.3 A Small QR Capacity Responding to Immediate Needs Can Make A Big Difference

In October of 1998 Ft. Jackson requested DSCP take action to fill all outstanding requisitions because they lost inventory accuracy with the installation of a new version of ACIIPS. DSCP, in turn, requested CAR's assistance in manufacturing critical shortages of the Women's Shirts because they did not have an active contract in place. This was especially important because the Army sends all recruits home on leave in Class "A" dress uniforms for Christmas early in December. The RTCs had shortages in three high demand sizes. Car placed Ft. Leonard Wood, the other Army RTC for women, on BIFRS with Ft. Jackson and used its limited production capacity to support both RTCs. CAR met all requirements by routinely producing its normal 200 ARN shirts per week for 5 weeks. This again demonstrated how a very small production capacity could support actual demand if total asset visibility is available and a balanced flow concept is used. By knowing exactly what the requirements were in real time, CAR only produced shirts that were needed immediately with its limited capacity. CAR was not able to rebuild the large buffers for the supply chain, but the Christmas Exodus was completed without any shortages.

This situation presented several great examples of typical problems and the potential benefits of a balanced flow system. First, when retail does not have accurate inventories, replenishment support becomes extremely difficult. With the loss of inventory accuracy, more inventory of everything is the only

immediate fix – and this is what Ft. Jackson demanded. Next, problems do not occur in isolation. DSCP was between contracts and out of stock at the same time that the inventory problem struck Ft. Jackson. DSCP had no visibility of inventory levels at retail, so they could only react by filling the RTCs' requisitions as they received them ahead of other customers. Had they filled Ft. Jackson's large requisitions, they would have not been able to meet the needs of Ft. Leonard Wood. However, with total asset visibility there was no real problem. We were able to concentrate the available, but limited, manufacturing resources on the sizes actually needed. CAR's extremely limited capacity was used to keep both RTC's from running out of stock. Finally, CAR had in place modular manufacturing that could turn production runs in less than a week. This contrasts sharply with traditional apparel manufacturing that takes 4 to 6 weeks to turn an order.

3.6 DEVELOPING THE BALANCED FLOW SUPPLY CHAIN CONCEPT

The evolution of the balanced flow concept began with the production of the shirts for Ft. Jackson in January 1997 and continues today. The basis of the concept is from the body of knowledge known as the theory of constraints (TOC) or constraints management. Additional learning and validation of constraints management principles came from the demonstrations discussed previously, from the study of the components of the existing C&T system, and from the work of other external sources. Following is a discussion of the TOC based lessons learned to date from all of these sources over the entire 3 years.

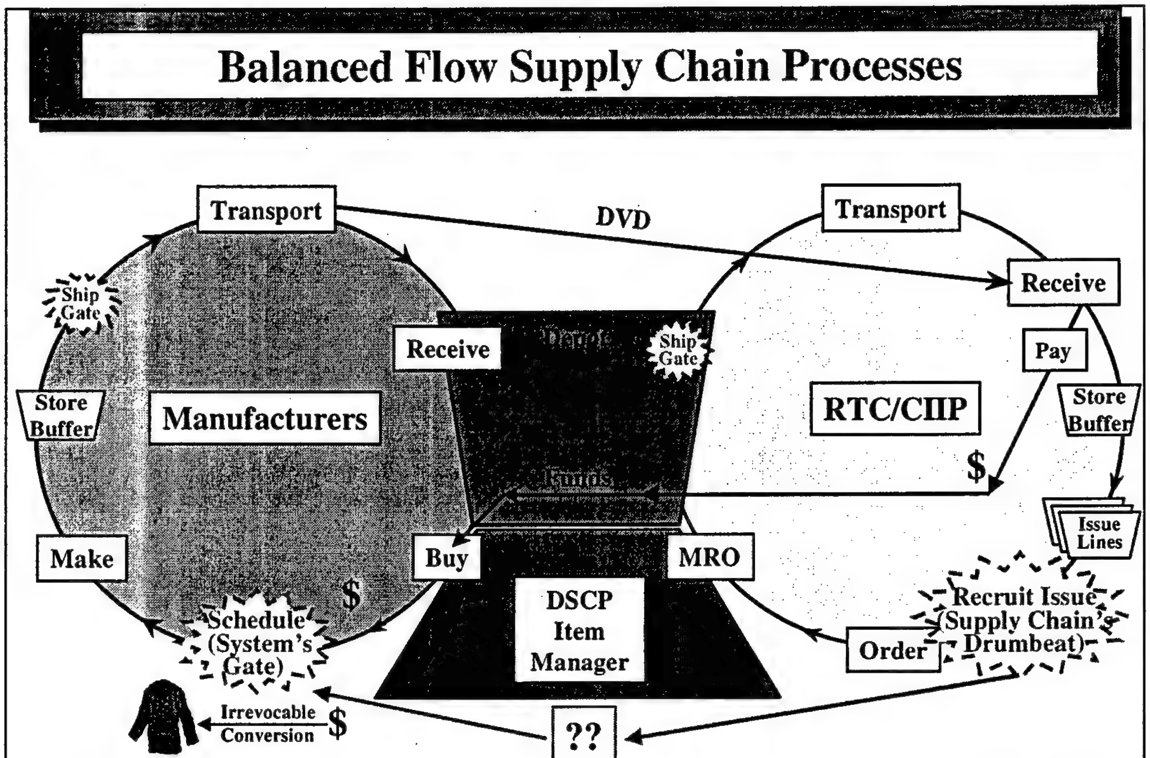
In May of 1997, CAR carefully re-examined the entire C&T ordering, manufacturing, and distribution system using TOC's logical problem-solving approach designed to identify core problems of large, complex systems. Once we identified the core problems, we used TOC's problem solving methodology for logistics known as "drum-buffer-rope" as we evolved the supply chain demonstration. The thinking process led to the identification of the core problems and the drum-buffer-rope (DBR) process was selected and implemented as the solution for the core problems. DBR is explained in Section 3.6.5. Since the solution consists of creating a balanced flow of orders up, and products back down the entire chain, we refer to the solution as the "balanced flow concept."

3.6.1 The Model of the Existing C&T Supply Chain

The current enterprise-wide C&T ordering, manufacturing, and distribution system is shown conceptually in the following chart. The RTC's sub-systems revolve as depicted on the right wheel and the procurement-manufacturing sub-systems revolve as depicted on the left. DSCP's wholesale buffers consisting of items and funds are the two points where these two sub-systems

come together. Major supply chain processes are shown and red starbursts are used to highlight those processes that are critical to DBR. These processes are discussed in following sections.

Chart 5 – Balanced Flow Supply Chain Processes



An enterprise-wide constraint management solution to provide all recruits all clothing items on time and at lowest total cost. Key Balanced Flow processes are shown in red.

Again, the objectives of the C&T system are (1) to provide all recruits all clothing items at the scheduled time and (2) to do this at the lowest possible total cost. This is a large, complex system of interdependent processes which are statistically connected by inventory and funding flows. Actions taken within any single process that affect inventory or funding do have effects on inventory levels and costs at other processes and the entire system. These statistical effects do not average out – they are additive and they are extremely difficult to predict. Often there are no obvious connections between effects and their causes. Local process owners improve their processes with no way of knowing the global effects of their actions. Often, local improvements actually degrade the performance of the overall supply chain. An example is the long-term problems caused by Ft. Jackson's logical action of increasing stockage levels. The balanced flow principles evaluate all changes in terms of global impact on the stated objectives of the entire supply chain. Global impact must be measured in terms of throughput (speed), inventory investment, and operational expenses.

3.6.2 Identifying the Core Problems of the C&T Supply Chain

The first step was to employ the disciplined, logical thinking process to identify root causes and core problems within complex systems based on the established objectives for the system. For this undertaking, we restated the ARN goal for the C&T system as "to issue recruits all items as scheduled at the lowest possible system-wide cost." We then applied the logical thinking process, in turn, to each of the two objectives of the goal:

1. Why can RTCs not issue recruits all items as scheduled?

2. Why can RTCs not reduce the cost of clothing recruits?

Almost two man-weeks were required to develop a 12-page logical flow diagram of the thinking process for all the problems of the C&T supply chain. This flow begins with the above questions and works its way, one logical step at a time, down to root cause problems. For example, the first step for Objective 1 was to brainstorm the answer to "What could possibly prevent the issuing of all recruits all items as scheduled?" Responses could be only one logical step removed from the question – no intermediate causes could be skipped. Root causes are located down the logical flow of causes at the edge of the sphere of influence of the people charged with improving the system. By definition, the one or two root causes that, if solved, would have the greatest impact on the entire supply chain are identified as the core problems. Logical problem solving of each ARN objective led us to the same two core problems.

3.6.3 The Core Problems are Batched Orders and Unbalanced Inventories

We found two core problems in relation to the ARN objectives. They were:

1. **The retail economic order quantity (EOQ) ordering systems batched demand and ordered (requisitioned) very large quantities infrequently.**

2. **Inventories were unbalanced across the entire supply chain.**

Additional key root cause problems included (1) uneven production requirements, (2) contractors had no capability to accurately forecast demand, and (3) contract delivery times that were shorter than production lead times.

The C&T supply chain consists of multiple processes, each of which is dependent on the performance of those processes that precede it in the chain. By definition, a system of interdependent processes always has one

constraint process that limits the system in relation to its goals. This constraint can be anything in the system, but it should be the natural constraint of consumer demand. This should be the clothing issue process for our C&T supply chain because the RTCs must always have all the right items in stock in the right quantities to meet the recruit demand. This is the same as consumer demand in a commercial supply chain. We quickly realized that the use of EOQ ordering (Core Problem 1) made the ordering system the constraint rather than recruit demand. Our challenge was to eliminate Core Problem 1 so recruit demand could become the constraint of the entire supply chain. Once all energy was focused on the core and root cause problems, we were able to stop attacking numerous symptoms and make significant progress.

3.6.4 Making Recruit Clothing Demand the Supply Chain's Primary Constraint

Once we defined the core problems and other root cause problems, we realized we were already taking proper corrective actions to eliminate our first core problem of batched EOQ orders. The second step in creating a balanced flow is to eliminate all large bottlenecks until the natural constraint becomes the largest bottleneck. The first core problem within the C&T supply chain was that the entire chain was reacting to large, infrequent requisitions rather than to the natural constraint of recruit demand. This ordering process was actually adding great variation to the system that resulted in unnecessary inventory investments, backorder management actions, and expediting at manufacturing.

Eliminating batched requisitions made the arrival of recruits the proper constraint of the entire supply chain and freed resources to focus on fulfilling the recruit demand efficiently. (Actually, since Ft. Jackson's ordering bottleneck of large, infrequent requisitions could not be eliminated, we made it moot by creating a weekly flow of partial shipments.) By ignoring requisitions and making partial shipments, we matched our manufacturing resources to the natural constraint of recruit demand rather than to the arrival of requisitions. Later with Parris Island, we created BIFRS-R to generate a weekly flow of small, predictable requisitions. However, we still had to protect our constraint process of recruit clothing issues from downstream recruit demand variation plus upstream manufacturing and distributing variations.

3.6.5 Protecting The Constraint Through Drum-Buffer-Rope

The third implementation step of creating a balanced flow is to protect the constraint and manage the entire supply chain by focusing every process on the constraint. As stated earlier we elected to use the logistical methodology known as drum-buffer-rope to protect our constraint of consumer demand. Following is a discussion of the elements of drum-buffer-rope.

3.6.5.1 The Drumbeat is Recruit Demand

It is obvious that any supply chain should produce and move products at some defined pace or rate. This pace should be established by the constraint of consumer demand – each time that an item is issued to a recruit should signal all the processes up the supply chain to take appropriate replenishment actions. This signal should be the drumbeat to which the entire chain responds or marches.

The key to protecting the natural constraint of recruit demand is through strategic buffer management so the right items are always available at the right locations when required. It is impossible to connect manufacturing directly to consumer demand so that production exactly matches demand all the time. A buffer must be built between manufacturing and demand to balance the risk of stockouts with inventory investment and operational expenses. This buffer should protect both the constraint and the manufacturing processes.

3.6.5.2 The Buffer is <u>All</u> of the Inventory in the Supply Chain

The buffer begins with the inventories at the RTC, but it also includes every item in the entire supply chain and is ultimately controlled by the release of new work into the supply chain. Our final buffer segment is the inventory at the RTC and we designate it as our "primary buffer" because it is directly connected to the supply chain's constraint. The removal of items from this buffer segment by recruits is the "drumbeat" to which the supply chain must manufacture and distribute replacement items. Strategic buffer management is simply maximizing inventory turns so that funds are turned into the "right" items and "right" items are distributed to the RTCs in lock-step time to the system's drumbeat. This drumbeat must be passed up the supply chain in some manner.

3.6.5.3 The Rope is a Fax and Balanced Flow Software

The primary buffer is protected by connecting it directly to the "gating operation" at the beginning of the supply chain and by connecting it directly to the inventory from which replenishment items are drawn. These connections can take many forms from simple visual signals to the Internet. An easily understood concept is described by the term "drum-buffer-rope" itself in which both ends of a supply chain are connected by a rope. Each time the consumer takes an item, the rope is pulled to signal the scheduler to put another one into production. This forces the chain to operate at the pace of consumer demand.

We began creating our rope with the weekly fax from Ft. Jackson. We used this logistical data (quantity on-hand, quantity due-in, and items issued) to

calculate how many items to ship to rebalance the inventories at Ft. Jackson. Next, we extended the calculations to generate the manufacturing requirements needed to rebalance the entire supply chain from manufacturing's work-in-process forward. We then added a small finished goods buffer so we could ship immediately and protect our manufacturing line from expediting to fill fluctuations in demand. Later with Parris Island, we redefined our "rope" by creating BIFRS. Our ARN "rope," consisting of total asset visibility, the ARN DataMart, and BIFRS became the missing link between recruit demand and plant scheduling shown on Chart 5.

3.6.5.4 How Drum-Buffer-Rope Works

In theory, every time a unit is removed from the buffer for processing by the constraint, an equivalent unit of raw material is introduced at the gating operation. It is self-evident that this prevents excess raw materials from entering and building up as excess inventory somewhere within the supply chain. It is also evident that this ensures the constraint is never starved for inventory because the supply chain is out of stock. Next, every time a unit is removed from the primary buffer, an equivalent unit is shipped from the replenishment buffer. Obviously, we can not make just one unit each time we consume one and we can not ship just one unit each time we consume one. The objective is to minimize make and move batch sizes until net batch handling costs exceed inventory investment savings across the entire supply chain. The balanced flow concept addresses optimum make and move batch quantities through decision support calculations.

These actions protect the constraint from each side of our supply chain as shown in Chart 5. First, we convert raw materials and funds only into items that are most urgently needed by the entire system in time to the drumbeat of consumer demand. Next, we protect the constraint by distributing from wholesale (shipping) only those items that are most quickly issued and paid for at retail.

Let's now consider in detail the manufacturing sub-system because it contains the primary gating process for the entire supply chain. Weekly scheduling is the critical process because this is where funds are irrevocably converted into items. If DSCP provides the contractor a weekly list of sizes that are required to re-balance the entire system in days-of-supply from work-in-process forward and these sizes are entered directly into production; scarce funds are never converted into more long-supply items. This solves the core problems of unbalanced inventories and batch ordering for the entire system and also picks up the added benefit of level production that, in turn, generates lowest possible item costs. Level production runs eliminate expediting and other unnecessary and costly management actions across the entire supply chain. In addition, it eliminates the large risk of not knowing

what production capacities will be required from week to week. Risk is reflected in higher item prices and/or lower profits.

Let's next look at the secondary RTC sub-system. The first process after recruit issue is ordering. In a commercial supply chain, we would eliminate the entire ordering process (it is not value added) and push replenishment forward as required by the retailer. However, military retail operations could not eliminate ordering because of legacy systems so we had to find other solutions to this problem. In addition, as discussed earlier, all RTC systems batch demand and are incapable of generating daily or weekly orders. Even if we could generate frequent orders, we would still have to go all the way around the complete RTC cycle before funds generated from a recruit issue are deposited into DSCP's account for reuse – and that takes up to 5 months! For Ft. Jackson, we ignored the requisitions and shipped partials. Later, for Parris Island, we replaced their ordering module with a balanced flow-ordering module. Thus, the core problems of unbalanced inventories and batched retail ordering were eliminated as we protected the constraint process of recruit demand.

3.6.6 Using the Day-of-Supply Concept to Balance the Supply Chain

When we first saw that some items and sizes at Ft. Jackson were vastly overstocked while others were out of stock, we recognized the need to level all inventories. All retail ordering systems are designed to do this, but they fail because they batch demand and treat each NSN as if it were totally independent of all other NSNs (sizes) of the same item. From a manufacturer's viewpoint sizes are not independent. All sizes of a single item are produced on one production line with minimum changeover costs. As a manufacturer, we would gladly run smaller batches more frequently to eliminate all the costs and problems created by expediting. We had to have a methodology for equating the demand for one size to the different demand for other sizes so we could re-balance the supply chain.

We decided to apply the military war reserve concept of days-of-supply to accomplish this with our recruit clothing. This concept uses a forecast of demand based on a force structure and operational pace to compute the number of days that each NSN in war reserves will last should a conflict begin. When funding is available to purchase additional war reserves, the NSNs that will last for the shortest number of days are procured first. In theory, when a war starts, all items will last approximately the same amount of time so no single item will become a war-stopper early because scarce funds are tied up in long-supply items. This was exactly the way we wanted to purchase manufacturing capacity with our scarce supply chain funds. The next question was how often should we attempt to rebalance our supply chain.

3.6.7 Weekly Re-balancing appears to be the Optimum

We were doing our cut-order-planning just like most other manufacturers. CAR's planner did a "rough cut" of our production requirements for Ft. Jackson once a week for the following week and passed these requirements to the manufacturing floor. The floor supervisor decided what to cut when within the week to meet shipping requirements at highest overall cutting and sewing efficiencies. Also, in the beginning, we did not want to overburden the small staff at Ft. Jackson with additional work faxing data – once a week was sufficient to support our rough cut scheduling.

This schedule created a weekly flow of shipping and manufacturing requirements. We also simulated depot stocks with our finished goods and material release orders (MROs) with our DD 250s which we generated once a week for replenishment of Ft. Jackson's inventory. This weekly flow can be contrasted to Ft. Jackson's history of only ordering each item 3 to 4 times a year. This also created a weekly flow of manufacturing orders instead of the normal 3 to 4 DVD orders per year per size. We found the size mix to be of almost no importance, but level production requirements from week to week are the envy of every manufacturer because this clearly results in the lowest possible manufacturing costs. We thus minimized weekly demand fluctuations, but we still had to accommodate annual seasonal fluctuations.

Our initial weekly re-balancing was validated later by the HWBDU demonstration at American Apparel. We needed about a week's worth of demand to generate sufficient orders; in addition, more frequent generation of production requirements would have to be held and batched for weekly rough-cut scheduling. We also learned the timing of the weekly BIFRS run was very important. It should be run just prior to rough-cut scheduling to take as much reaction time out of the supply chain as possible. If we do not pay attention to this, we could lose up to a week of time between collecting the updated inventory data and launching new production based on this data.

3.6.8 Ideal Manufacturing Requirements are Level All Year.

Military manufacturers do not have the ability to increase and decrease production throughout the year to match the large seasonal shifts in demand. They require level manufacturing requirements in weekly increments all year long so they can maintain a stable workforce that is capable of meeting quality and delivery standards. They do not have commercial items available to fill in or take out of production as military needs change.

3.6.9 The Drumbeat of Recruit Clothing is Seasonal

Recruit clothing issues are seasonal because of the heavy influx of recruits in the summer following high school graduation. We approached the

accommodation of this seasonal demand from a military clothing manufacturer's viewpoint.

We began our calculations by obtaining historical demand to determine the size mix for each item (the tariff of sizes) and the recruit accession plan to forecast future demand (the drumbeat) at the item level. To generate level weekly manufacturing requirements, we divided the annual forecast of recruits by 52 weeks per year for each item. We then multiplied this number by the estimated number of items per recruit. We needed to make only 84 shirts per week for Ft. Jackson. Later we changed from this annualized weeks-of-supply to annualized days-of-supply (ADOS) as the lowest common unit of demand for consistency and ease of understanding in our calculations. We now had a forecast of demand directly driven by the drumbeat of recruit demand. This forecast is viewed as a two-sided coin. On one side, we have the ADOS and, on the other, we have the number of items. The 1ADOS is the conversion factor between days and items.

Our approach to seasonal demand became more refined during the HWBDU demonstration. We defined the components of the inventory objectives for the supply chain as basic or seasonal. The basic inventory objective (BIO) was the static amount of inventory we wanted to always have in the supply chain. It was simply the sum of the inventory desired in each segment of the supply chain. The seasonal inventory objective (SIO) was the variable amount of inventory we wanted in the supply chain based on the week of the year.

Given that we wanted to hold manufacturing capacity relatively constant all year, the SIO began at zero at the end of the summer surge and peaked just before the next summer surge. We computed the SIO for each of the 52 weeks of the year based on recruit projections and steady-state production at the annual average weekly rate. We then added the weekly SIO to the BIO for a total inventory objective (TIO) for each week of the year. This moved our supply chain targets up and back down on our management charts as we moved through the year.

3.6.10 Forecasting must be used, but Its Inherit Errors can be Minimized

Forecasting errors were identified as one of the main causes of unbalanced inventories. Specifically, long-term forecasts at the NSN level that are locked into production requirements cause unbalanced inventories. We knew we could not eliminate forecasting, but we had to minimize the impact of forecast errors on our supply chain. Our ADOS concept achieves this in two ways. First, it eliminates the long-term forecasting at the NSN level. Long-term forecasting is only done at the item level. We use the tariff of sizes to explode an item to individual sizes and to do short-term forecasting only for the length of the supply chain. Next, it eliminates locking in production at the

NSN level until the last moment. Now size requirements are computed weekly just before rough-cut scheduling takes place. Thus, forecasting is still used to shorten the supply chain, but its importance and errors are minimized.

3.6.11 The Role and Importance of Size Tariffs

We learned that size tariffs are an integral part of forecasting. In the old procurement system forecast errors are the major cause of stockouts and excessive inventories. We can not operate without forecasts, but we can limit the impact of their inherit problems. There are three sources of errors when forecasting apparel demand for recruits based on recruit accession plans. First, is the error in the recruit forecast itself, but, as discussed earlier, the recruiting commands work very hard to minimize this error so it is small. Next is the error in the number of items consumed per recruit. This error is also small because basis-of-issue rates are set and replacement purchases are small, well documented, and very predictable. Finally, there is the error in the predicted size mix or the tariff of sizes for each item. This is the largest source of variation, but it too is very predictable if the recruit population is large enough. Through experience, we learned that a population of 300 or so recruits is required for the tariff prediction to be correct. This equates to about a week of recruit accessions, which matches well time-wise with weekly rough cut scheduling at manufacturing.

Again, the problem with the old system is that forecasts are made at the detailed NSN level and locked-in well into the future through inflexible contracting actions. The longer the forecast horizon and the more detailed the forecast, the larger the forecast errors. Corrective action then proves to be very difficult. Managers are blind concerning timely inventory status in much of the supply chain, manufacturers prefer to make all of each size at one time, and contract modifications to change size-mixes are very difficult. DSCP has worked more flexibility into contracts and the balanced flow system now minimizes the time horizon over which operational forecasts must extend. In fact, contracts now accurately lock in the quantity of an item required at the item level based primarily on the accession plan and the item's basis-of-issue plan. The wholesale item manager attempts to level weekly production requirements at the NSN level within the limits of the contract. BIFRS-W is the tool that will now take this the final step by using the tariff, but over a much shorter forecast horizon to determine specific manufacturing requirements.

As discussed earlier, the ADOS is very accurate at the item level. The tariff is used to explode the item-level forecasted daily demand into the NSN-level forecasted daily demand. With BIFRS-W, the forecast period is much smaller and NSN changes are much more flexible than with the old forecast and

procurement system. The forecast period now begins when BIFRS-W is run each week and this is only one or two days before the beginning of manufacturing. For normal operational replenishment, the forecast period is the length of the supply chain. For emergency replenishment, the forecast period is the manufacturer's production leadtime plus shipping time. Errors and inventory in-balances are caught and corrected automatically each week. Once properly established, buffers will protect recruit demand and manufacturing capacity with the smallest possible total inventories.

Tariff errors will result in ordering some sizes slower or faster than anticipated. If the error is small to moderate, the buffers will prevent stockouts, but if the error is large enough, the buffers can be exhausted and stockouts will occur. In either case, the tariff is self-correcting over time for BIFRS-R and BIFRS-W. Retail item managers at Parris Island have early visibility of potential problems through the Critical Balance Report and can take efficient corrective action to prevent stockouts.

3.6.12 Classical Reengineering is Required only after Balanced Flow is Achieved

Once inventories are balanced across the supply chain and stockouts are eliminated at the RTCs, tariffs will become accurate (larger sizes will no longer be altered and reordered when smaller sizes are out of stock). The largest remaining opportunity for improvement will be reducing process times (variations and averages) for each segment of the supply chain. Manufacturing production lead times will offer the greatest opportunities because they are the longest segments with the most impact on item and inventory investment costs. However, improvements in this area will not be as easy as improvements realized through balancing the inventories across the supply chain. Up until this point we have only been changing the ways we work with inventories across the supply chain. Now, we must change processes using classical reengineering and this will involve many people in a massive change process. However, the objective of minimizing RTC inventories could be further realized relatively easily.

3.6.13 OST is Now the Constraint to Reducing Parris Island Inventories

The primary determinate of RTC stockage objectives is OST. Simply stated, a RTC must have sufficient stocks on hand to support the number of expected recruits for the amount of time it takes to replenish inventories. The number of recruits that reach the issue lines determines the levels that must be on the line and the OST determines the number of days that must be stocked at this level. It appears the processes involved in replenishment do not have to be reengineered to improve OST significantly. They just need to be optimized to minimize the up-side variation and the averages. The real problem is that the RTC does not know which few NSNs will require long OSTs, so they must carry sufficient inventories of every NSN to cover the up-side variations.

We established a flow of BIFRS-R generated requisitions through DSCP and the Albany Depot to minimize OSTs. Parris Island issues most of its clothing Monday and Tuesday night. They replenish the lines on Wednesday and post this to MUMMS Wednesday night. We then run BIFRS-R on Thursdays. Requisitions hit SAMMS through ASCOT by Thursday night and material release orders (MROs) are generated immediately for all that do not have item manager flags. These MROs are filled by Albany on Friday. Since Parris Island has labor available to receive shipments on Monday, Albany loads trucks on Friday or Saturday for Monday morning delivery at Parris Island.

The problem is that a large number of these requisitions flow into Albany over the next two weeks rather than with the initial batch. This spreads the distribution and extends the up-side OST to approximately 3 weeks rather than the planned 4 days. This means that the RTC has to carry over two weeks of extra inventory to cover systems problems when stocks are available. This is now the constraint to making further reductions in RTC inventories.

When we first identified this problem, we thought the source was the old system that Albany was using. However, the same problem continues now that Albany is on the standard automated depot system.

3.6.14 Wholesale Item Managers spend much of their Time Managing Backorders

We documented the work that wholesale item managers do by working with 12 managers over several weeks in the spring of 1997. Their work is broken into 5 areas by time spent in each; generating forecasts (10%), generating purchase requests (10%), order fulfillment (40%), asset management (30%), and other (10%). Order fulfillment is mostly managing backorders to be sure the highest priority customers have their needs satisfied first. This validated the need to continue with the balanced flow system because there was more than sufficient inventory to cover all needs. It also became clear that implementation of the balanced flow concept would alter item manager jobs significantly. The item managers validated that we were on the correct approach with the balanced flow concept and we learned that our approach was almost identical to their process of managing backorders.

3.6.15 BIFRS-W Minimizes and Manages Backorders

It became clear during the "emergency" manufacturing of Army Women's shirts for Christmas leave in 1998 that BIFRS-W actually works just like wholesale item managers work when they reach an emergency situation. They first get the status of what is really in the supply chain by asking manufacturers and RTCs what they have in their supply chain segments. They next verify the expected consumption rates of each priority customer for the next few weeks. If possible, they allocate the available assets to keep all

high-priority customers from running out of stock. They expedite shipments by releasing partial backorders to bypass unnecessary supply chain segments and they have shipment instructions ready for the manufacturers before work-in-process turns into finished goods. Finally, they ask manufacturers to expedite critically short sizes. BIFRS-W brings two significant improvements to this process. First, it is automatic so it does not require the manual item manager intervention with associated resource requirements. Second, by operating this way all the time, BIFRS will minimize the number of emergency situations by ensuring manufacturers routinely make only sizes in shortest supply every week.

3.6.16 Current Measurements Guarantee Failure in Meeting the ARN Objectives

Performance measurements for wholesale item managers were properly established years ago to ensure critical RTC requisitions were filled as quickly as possible. The critical measurement, supply satisfaction, is the percent of recruit clothing requisitions that are filled immediately upon receipt of the requisition at DSCP.

However, this measurement institutionalized the wrong constraint for the entire supply chain. It focuses the energy of wholesale item managers on requisitions, not on recruit demand. As discussed earlier the drumbeat of the entire supply chain is recruit demand and this is very predictable. In fact, the recruiting commands work very hard to minimize deviation from the Accession Plans because they are the basis of the entire annual recruit training budgets. On the other hand, large, infrequent requisitions add great variation to recruit demand. Requisitions batch demand, are submitted infrequently, and are often driven by policy decisions such as financial need or the fear of stockouts rather than recruit demand. When wholesale managers and manufacturers activate resources to completely fill large requisitions, they are using scarce resources to deliver many items that will not be needed by the consumers as quickly as will other items. These resources must be refocused on consumer demand rather than batched demand defined by large requisitions.

3.6.17 Manufacturing Capacity is the C&T Supply Chain's most Scarce and Precious Resource

We learned that the movement of inventory within the supply chain is of secondary importance to having inventory available to satisfy consumer demand. Manufacturing capacity is the most precious and scarce resource within the entire supply chain and it must be aligned with recruit demand by all item managers. The movement of inventory within the supply chain must not increase the burden on manufacturing and this is exactly what we found was occurring. If the only demand that wholesale item managers can see are requisitions, then they have no choice but to react to them. When retail item

managers order far more than they need; wholesale item managers spend a great deal of their time (supported by huge inventories or backorder management) shipping inventories that should remain upstream in the supply chain for maximum flexibility. Thus, wholesale item managers spend a lot of time on non-value added work including the passing of this non-value added work to the manufacturers in the form of expediting.

This cycle can now be broken for the first time with the tools provided by the ARN. First, orders from the Marine Corps RTCs are flowing properly now so responding to them is no longer a significant problem at wholesale or manufacturing. Next, total asset visibility enables the managers to see consumer demand, inventory levels, and requisitions. Finally, BIFRS-W minimizes the long and short inventory positions in the entire supply chain. In the future, QLM-Central will move inventory properly down the supply chain with minimum intervention from item managers.

3.6.18 Performance Measurements must Optimize Supply Chain-wide Performance

As each item is activated on BIFRS-W, the primary performance measurement should be changed from supply satisfaction to supply chain-wide measurements that include order-ship-times, retail stockouts, inventory turns, total inventory investments, expedite requests, and operational costs. This will guarantee success in meeting the ARN objectives of eliminating stockouts, minimizing inventories, and minimizing operational costs.

3.6.19 Efficient Supply Chains Can Limit Go-To-War Surge Response

The ARN's research and implementation efforts should return to the manufacturing lines once the logistical opportunities are realized. Manufacturing improvements will again offer the primary opportunities for improvement in relation to the stated ARN objectives. In addition, it is now clear that manufacturing improvements will become even more important, but in a different way, than previously envisioned <u>because</u> of the logistical improvements. The only way to meet all three ARN objectives at the same time is to increase order and inventory turns first up and then back down the entire supply chain. This begins when the RTCs requisition replenishment items up the supply chain and comes back down the supply chain from production scheduling through recruit clothing issue. Reducing time and reducing inventory are one and the same. Increasing inventory turns through logistical improvements removes inventory from the supply chain. This can cause new go-to-war problems!

In the past, surge requirements were met primarily by accelerating the movement of excessive raw materials and finished goods down the supply chain through extraordinary efforts across the entire supply chain. As the

VPV makes significant improvements in shortening the supply chain, this excess inventory will not exist when it is needed for future surges.

Future ARN efforts must continue the balanced flow efforts and focus on three additional areas to optimize the complete, wartime C&T supply chain:

1. Order-ship-times must be improved. This includes eliminating system delays and eliminating backorders to reduce up-side variation and averages.

2. Manufacturing lead times must be reduced. Once logistics improvements are realized, manufacturing lead times will be the next constraint relative to the existing goals of the C&T supply chain.

3. Upstream wartime surge capabilities must be addressed because balanced supply chains can respond very quickly, but excessive raw material inventories called upon in the past will no longer be available.

4. MANUFACTURING DEMONSTRATION ACTIVITIES

Year 3 brought many changes to production line manufacturing within the CAR facility. These changes included a major shift in philosophy of manufacturing small quantities of military garments to a more integrated manufacturing environment with commercial products, introduction of new military garments for the Marine Corps, and addition of a totally different manufacturing line for demonstration in the knit product area. There were many additions of new manufacturing equipment on the demo floor. Indirect labor charges for manufacturing were reduced. Software for support of manufacturing military products was substantially improved, including complete integration of CARGOES, our pre-production software, into ARN AIMS, ARN's comprehensive software package. Each of these activities is addressed separately in the following sections.

4.1 CARGOES is Integrated into AMA

Georgia Tech (GT) began the development of an overall apparel manufacturing architecture (AMA) as a separate ARN effort prior to Year 1 of CAR's contract. The purpose was to ensure standardization of all ARN research efforts through process and data documentation within the AMA.

CAR began the development of its automated ARN system in Year 1 to support all activities from order entry through billing. Initial emphasis was on the pre-production, special measurement operations in support of the

special measurement manufacturing conducted in Year 1. This initially consisted of many Excel spreadsheets. During Year 2, we conducted a formal reengineering effort on our processes from order entry to collecting payment. Our goal was to minimize our production leadtime.

Once we had all the functions properly integrated, we realized we needed a relational database on our local area network in order to get our production lead time under 7 days. We selected Microsoft Access supported by programming in Visual Basic for our software and named it CARGOES for CAR Government Order Entry System. CARGOES was developed at a level of detail below that of the AMA and included the implementation of special measurement (SM) operations that were not addressed by the AMA.

Georgia Tech integrated the functional details of CARGOES into the AMA and used the tables to expand their on-going development of an automated package that became known as ARN-AIMS for ARN Apparel Information Management System. This brought CARGOES into full compliance with the AMA standardization.

4.2 ARN-AIMS is implemented at CAR

Prior to Year 3, the ARN decided that ARN-AIMS would be the ARN software package that would be developed and made available to manufacturers for support of government apparel manufacturing. It would include the SM module under development at CAR. At the beginning of Year 3 Georgia Tech and CAR agreed that ARN-AIMS would include all modules except for CAR's SM module which CAR would complete separately. At that time, CAR terminated the development of CARGOES except for the SM portion and Georgia Tech continued the development of ARN-AIMS anticipating commercial application.

Martin Manufacturing had the DSCP special measurement dress shirt contract and was scheduled to receive a final commercial version of CARGOES in the Fall of 1997 as part of the CAR Demo Contract. Martin had no automated CAD capabilities or equipment when CAR first visited in the spring of 1997. In fact, CAR assisted in the set-up of their first computer and learned that taking a company from no automation to full CARGOES was a very challenging task. In the summer of 1997, CAR installed the then existing version of CARGOES at Martin and added new features such as dual invoices to meet Martin's particular needs. In November of 1997, CAR and GT decided to delay the installation of full CARGOES at Martin until February of 1998 so ARN-AIMS could be completed and installed instead. We did not feel Martin could handle the implementation of another version of CARGOES followed soon thereafter by the implementation of ARN-AIMS.

Learning two new automated systems within a few months would have been very unproductive for Martin.

An operational version of ARN-AIMS was not available before the Martin SM shirt contract expired in June of 1998 so it was not installed at Martin. CAR modified ARN-AIMS to get it running at CAR in July of 1998. By then, a decision had been made to let a commercial software company "commercialize" ARN-AIMS prior to future implementation. No action has been taken on this "commercialization." In addition, the decision was made to let CAR manufacture all 28 SM dress shirts beginning in Year 4 to complete the files and automation steps for each item. All options remained open in Year 5 to continue the SM production at CAR, to move part or all of it to DSCP, or to move part or all of it to commercial software or apparel firm(s).

Throughout Year 3 CAR upgraded many portions of the basic ARN-AIMS software to make it more robust. CAR integrated the CAR-developed special measurement, order tracking, finished goods inventory, shipping, and invoicing modules into ARN-AIMS. CAR also added more electronic commerce features so that ARN-AIMS now receives orders by automatic download from EDI as well as by manual input. We also added an electronic payments section for electronic funds transfer. Each improvement brought us closer to our vision of completely automated, immediate manufacturing of SM orders.

Improvements continue to be added as the experiences of the CAR demo indicate a need for a new feature or an improved function. By the end of Year 3, the modified ARN-AIMS was working extremely well for CAR. However, "commercialization" would still require about two man-months of effort by a programmer fully knowledgeable of its contents and up to triple that time by a programmer who is not familiar with it. In addition, a lot of work would have to be done to tie this updated version of ARN-AIMS into the legacy systems of any commercial firm.

It became clear to CAR that the ARN needed to break ARN-AIMS into stand-alone modules and rewrite it to facilitate interface with existing automated business systems. It was clear that ARN-AIMS would have to connect efficiently to existing accounting, manufacturing, logistics, and billing systems to be of value and interest to defense manufacturers. Different manufacturers have need of different modules.

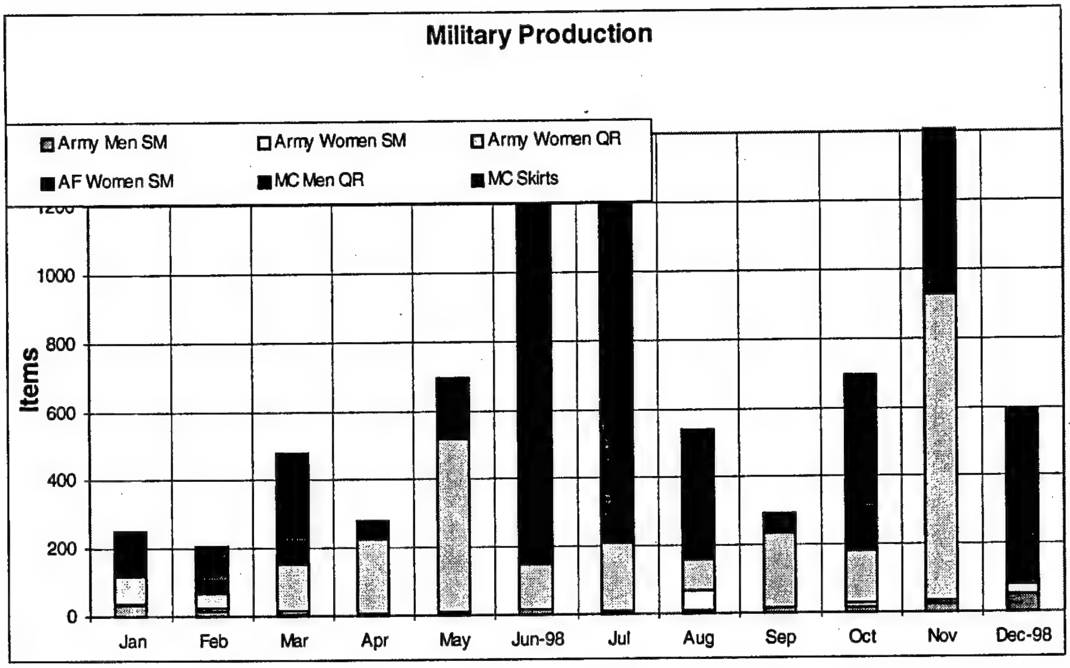
4.3 MILITARY GARMENT PRODUCTION AT CAR DURING YEAR 3

CAR began the demonstration in Year 1 by making 50 quick response (QR) overblouses per week for Army women at Ft. Jackson. Special measurement Army and Air Force shirts quickly became the focus throughout Year 1 and continued through Year 3. During Year 2, the QR production increased to 100 shirts for Army women at Ft. Jackson plus up to 100 SM shirts each week. During Year 3 we initiated the teaming project with the Marine Corps. This included supply chain research and manufacturing of Marine Corps shirts. We added 40 end-of-tariff sizes of the Marine Corps Men's long sleeve shirts to our weekly manufacturing in support of the Parris Island and San Diego RTCs. We made up to 100 Marine Corps Men's long sleeve shirts per week for these RTCs beginning in February 1998. The manufacturing and shipping requirements were generated using the new Balanced Flow Software.

Late in Year 3, DSCP asked CAR to fill a few emergency orders of SM Marine Corps Women's shirts. We used the techniques previously developed for the Army and Air Force SM shirts to immediately meet all requirements.

The following chart shows the total production of each military garment at CAR during Year 3. The planned capacity of 800 shirts per month was exceeded when both RTCs initially ordered full cases of the Men's Long Sleeve shirts in June and July. Once we could ship the quantity each RTC needed in commercial packs rather than full cases, this demand leveled out. The surge in Army Women's QR shirts in November was in support of the Christmas exodus discussed earlier.

Chart 6 - CAR's Production Workload for Year 3.



4.3.1 Military Shirts are produced on the Automated Commercial Line

CAR initially set up a military shirt manufacturing line with equipment that approximated the technologies found in the military contractors' facilities. Because of the relatively small quantities of special measurement and QR military shirts produced each week at the CAR demo, military shirt manufacturing had been handled by two to three operators on this military line. The operators were highly skilled, each capable of manufacturing a complete garment. The equipment consisted of versatile but in general not highly automated sewing machines. The work setup was similar to a module except that a number of operations had to be performed on one-of-a-kind machines located outside of the module in CAR's commercial shirt production line.

In contrast, commercial shirts were produced on a highly automated line in an absolute minimum PLT. Although the military line was highly flexible, it was not conducive to high individual operator productivity and production could not be ramped efficiently to high levels. Of greater concern was the fact that no PLT and costing data was being collected for military shirts on the automated line so no comparisons of time and cost could be made.

In the first month of Year 3 CAR published the first comprehensive BIFRS management chart showing the balanced flow concept across the entire supply chain for the Ft. Jackson shirts CAR was manufacturing. This new balanced flow system generated very manageable weekly production requirements that were well within CAR's weekly capacity. We could turn

our focus to improving the manufacturing line once we corrected the ordering process. During Year 3 all military shirt manufacturing was totally revamped within the CAR demo. We believe this will be the proper sequence of events within the defense apparel manufacturers after they are active on the balanced flow process.

The decision was made to integrate all military shirt production into the commercial shirt manufacturing line. In order for this to occur, a number of machines had to be added to the individual modules, particularly the collar module. Styles and operations had to be added to the Unit Production System that controls the movement of shirts through final assembly.

We felt that we could integrate the military shirts onto the automated commercial line if we could standardize a few military operations with our commercial operations. We have as much automated equipment on the commercial line as possible because it de-skills jobs and enables consistently higher quality production at lower costs on most operations. However, changeover times on some automated equipment can be excessive. This is very costly for the short runs between changeovers that we do at CAR. The collar area was our greatest concern since we need to use automated creasebands as much as possible.

Permission was received from DSCP to use our commercial band shapes for the men's style SM military shirts. This change meant that only the large collars (greater than 18.5) used for a large number of special measurement men's shirts and the women's collars had to be made totally manually. This was required because we did not have templates for these large collars.

A block diagram of the manufacturing floor as it is currently configured is shown in the following Chart. Chart 7 lists the equipment in each block. Essentially all of the automated equipment has now been used on military shirts.

Chart 7 - CAR's Production Floor Layout

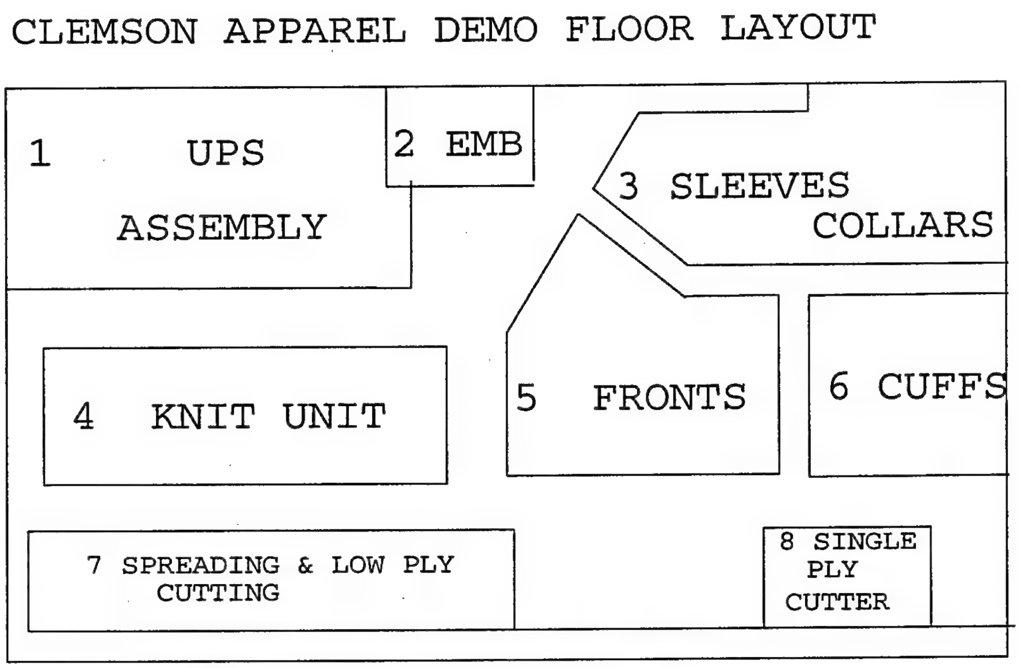


Chart 8 – CAR's Demo Floor Equipment

Area No.	Equipment
1	Wilcox/Gibbs 515 - 2 needle safety stitch Brother Exedra DB2 - single needle lockstitch/drop feed Pegasus EX – 2 needle safety stitch Pegasus EX – 2 needle safety stitch Pfaff 563 – single needle lockstitch, drop feed Wilcox/Gibbs 515 - 2 needle safety stitch U.S. Blindstitch – single needle blindstitch Juki DLN 5410 - single needle lockstitch Singer 691 - single needle lockstitch, drop feed Singer 691 - single needle lockstitch, drop feed Reece – Buttonsew w/FAD Durkopp 556 – Buttonhole (inverted buttonhole) Juki DLN 5410 - single needle lockstitch, needlefeed Singer 591C200G - single needle lockstitch, needlefeed Singer 591 D200G - single needle lockstitch, drop feed Juki MB-377 – manual feed button sew

2	Singer GT226S – 2 head embroidery 6 needle
3	Reece 8400 – Ultrasonic stays Kannegeiser – turntable press 2M Bandcreaser – collar bands Adler 973 – collar run Lunapress cp-323s – turn and trim collar points Pfaff 3334 – topstitch collars Brother LH4 – buttonhole collar points Adler 272 – single needle lockstitch, needle feed Juki MB-373 – buttonsew w/ feeder Juki LBH-791 – buttonhole w/ auto adjust table Lunapress CP-131R – collarpress Singer 591C200G – single needle lockstitch, needle feed U.S. LF600 – single needle chainstitch, sleeve hem Pfaff 561 - single needle lockstitch, needle feed Durkopp 273 - single needle lockstitch w/pullers Mitsubishi PKL – doghouse tacker
4	Brother CB3 – buttonsew w/feeder (on TSS stand) New York Sewing Attachment – auto placket Willcox/Gibbs 515 – 3x3 gauge conv. to 1 needle chnstitch Juki DDL-8500-7 – single needle lockstitch, drop feed Singer 591C300GDW - single needle lockstitch, needlefd Juki MO-3904-E – single needle overlock w/auto backltch Union Special 57800wz – 2 needle, bottom coverstitch Atlanta Attachment #213 – auto bottom hem Pfaff 1053 – single needle drop feed lockstch w/DC drive Juki LBH793N-S – buttonhole Juki MOR-3916E – FF6-300 2 needle safety stitch Brother DB2-B791 – 413B single needle N.feed lockstitch Brother DB2-B791 – 415 single needle N.feed lockstitch Willcox/Gibbs 515 E-32 – 430 233 5x5 conv. to 3/8" binding Silverman – A38 XLC placket creaser
5	Juki MO-3904 – single needle 3/16" overlock Universal 8660 – snap indexer Universal 8661 –post indexer Jet Sew 2701 – V-pocket hemmer Jet Sew 2531 – pocket set, 5" wide mil., 4 5/8" round Astechnologies – buck press U.S. 39500 – single needle overlock 1/8"gauge

5 cont'd	**Brother Exedra – single needle drop feed** **Singer 591C200G – 1 needle lockstitch, needle fd, topstch** **Pfaff 5487 – single needle chainstitch w/ top feed** **Juki DDL-5550 – single needle lockstitch, drop feed** **Singer 591D200GD - single needle lockstitch, drop feed** **Veit – steam iron w/ vacuum** **U.S. 54400 – 9 needle chainstitch w/puller, ¾" gauge** **Kansai Special – 2 needle chainstitch w/puller, 1" gauge** **Jet Sew 2621 – auto front & centerplait, 1" hem** **Juki ACF-171-791 – buttonhole index** **Juki ACF-161 - buttonsew index** **Durkopp Adler 805 – pocket set** **Pfaff 3588 – pocket set** **Durkopp Adler 576 – buttonhole pockets**
6	**Durkopp Adler – manual cuff run** **Singer 371 – buttonhole** **Juki MB373 – buttonsew** **Adler – profile for cuffs** **Durkopp Adler 961 – topstitch w/brimato press**
7	**Eastman adv.3000 – cloth spreader** **Gerber S3200 – low ply auto advance cutter** **Eastman Blue Streak – 6 ½" straight knife**
8	**Cutting Edge – single ply cutter**

4.3.4 Manufacturing Indirect Labor Costs Are Reduced

During Year 3, actual indirect labor costs were 20% less than the proposed costs ($239,831 vs. $298,190). In addition, this reflects a significant reduction from the budgeted costs of $549,910 of indirect labor for both Year 1 and Year 2.

5. BENEFITS SUMMARY

To date the primary value of the manufacturing demonstration to the ARN has been to provide a window into the entire supply chain from the viewpoint of the manufacturer. We learned that the supply chain must be driven by having the manufacturer introduce new production orders in a flow that re-

balances the entire supply chain each time they do scheduling. The best management decisions are made when the impact on the entire supply chain is known. This includes impact on throughput, inventory investment, and operational costs across the entire supply chain. As the manufacturer of Marine Corps shirts, we were driven to understand the importance and impact of decisions made at the recruit training center, at the wholesale level, and at manufacturing on each of the other elements of the supply chain.

The next largest area of value has been the accomplishments in pre-production. This includes software for QR production as well as special measurement production. Manufacturing, and specifically manufacturing leadtime, will become the largest opportunity for C&T supply chain improvement after the supply chain logistics opportunities are realized. CAR's production line continues to demonstrate the ultimate in minimum lead-times. Military and commercial garments are routinely shipped three workdays after production commences. This can be compared to the industry standard of 5 to 6 weeks.

6. ACRONYMS

1ADOS – One average annual calendar day of supply (quantity of items per day).
A0A – Document identifier code for an ordering requisition.
A0E – Document identifier code for an order with exceptional following data.
ACIIPS – Automated Clothing Initial Issue System.
ADOS – Annualized Days Of Supply.
AMA – Apparel Management Architecture.
ARN – Apparel Research Network.
ARN-AIMS – Apparel Research Network's Apparel Information Management System.
ASCOT – Automated System for Cataloging and Ordering Textiles
ATI – Average Total Inventory.
BIFRS – Balanced Inventory Flow Replenishment System.
BIFRS-R – Balanced Inventory Flow Replenishment System – Retail.
BIFRS-W – Balanced Inventory Flow Replenishment System – Wholesale.
C&T – Clothing and Textiles.
CAR – Clemson Apparel Research
CARGOES – Clemson Apparel Research's Government Ordering Entry System.
CDUM – Consumer-Driven Uniform Manufacturing.
CIIP – Clothing Initial Issue Point.

DBR – Drum Buffer Rope.
DoD – Department of Defense.
DOS – Day Of Supply.
DSCP – Defense Supply Center, Philadelphia.
DVD – Direct Vendor Delivery.
EDI – Electronic Data Interchange.
EOQ – Economic Order Quantity.
FG – Finished Goods.
HWBDU – Hot Weather Battle Dress Uniforms.
MILSTRIP – Military Standard Replenishment System.
MUMMS – The Marine Corps retail inventory & replenishment management system.
NSN – National stock number.
OL – Operating Level.
OST – Order Ship Time.
PLT – Production Lead Time.
POS – Point Of Sale data.
QLM – Quality Logistics Management retail software system.
QR – Quick Response.
RO – Requisition Objective.
ROF – Reorder Frequency.
ROQ – Reorder Quantity.
RP – Reorder Point.
RTC – Recruit Training Center (includes Army CIIPs).
SAMMS – Standard Accounting and Material Management System.
SL – Safety Level.
SM – Special Measurement.
SS – Short sleeve.
TOC – Theory of Constraints.
VPV – Virtual Prime Vendor.
WIP – Work In Process.